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TABLE OF CONTENTS

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service • Division of Radiological Health

Section I—Air and Fallout

FISSION PRODUCT BETA ACTIVITY IN AIRBORNE PARTICULATES AND PRECIPITATION

Continuous surveillance of gross beta activity in air and precipitation provides one of the earliest and most sensitive indications of changes in environmental fission product activity. Although this surveillance does not provide enough information to assess human radiation exposure from fallout, it is widely used as the basis of alerting systems for determining when to intensify monitoring in other phases of the environment.

Surveillance data from a number of national programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. Data provided this month by programs of the Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization are presented individually in tabular form and are also shown by beta concentration isograms in figure 4.

1. Radiation Surveillance Network, January 1964

Division of Radiological Health, Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) of the PHS Division of Radiological Health which gathers samples from 73 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel trained in procedures necessary to obtain the measurements as described and presented below.

Air

Airborne particulates are collected continuously on a carbon-loaded cellulose dust filter 4 inches in diameter. A volume of about 1800 cubic meters of air is drawn through the filter during the 24-hour sampling period by a high volume centrifugal blower.

The filters are forwarded to the Radiation Surveillance Network laboratory in Rockville, Maryland, and measured using a thin-window, gas-flow proportional counter, calibrated with a 38,700-pc Sr^{90}–Y^{90} standard.[1] Each filter is counted at least 3 days after the end of the sampling period and again 7 days later. The initial 3-day aging of the sample eliminates interference from naturally-occurring radon and thoron daughters. From the two counts, which are separated by the 7-day interval, it is possible to estimate the age of fission products and to extrapolate the activity to the time of collection. The extrapolation is performed by using the Way-Wigner formula (*1*).[2] The daily concentrations and estimated age are reported by the PHS in a monthly RSN report (*2*).

The January 1964 fission-product beta concentrations in surface air (extrapolated to the time of collection) are given in table 1. RSN data, along with Canadian and Mexican air data, are represented by isograms in figure 4.

[1] The Sr^{90}–Y^{90} source currently used as a standard was used from April 1962 to August 1963 as 40,000 pc total activity. Beginning with September 1963 data, the nominal activity of the standard was adjusted for decay (about 2½ percent per year) to 38,700 pc.

[2] $AT^{1.2} = C$, where A is the activity, T is the time (in any time unit) after fission product formation, and C is a constant equal to the activity at $T = 1$.

FIGURE 1.—RADIATION SURVEILLANCE NETWORK SAMPLING STATIONS, JANUARY 1964

Precipitation

Continuous sampling for total precipitation is conducted at most stations on a daily basis, using funnels with collection areas of 0.4 square meter. A 500-ml aliquot of the collected precipitation is evaporated to dryness, and the residue is forwarded to the laboratory for analysis. If the collected sample is between 200 and 500 ml, the entire sample is evaporated. When a sample is smaller than 200 ml (equivalent to 0.5 mm or 0.02 inches of rainfall), the volume of precipitation is reported, but no analysis is made.

In the laboratory the gross beta activity in precipitation is determined by counting the evaporated sample by the same method used for analyzing the air filters, including the extrapolation to time of collection. Deposition for the sample is determined by:

$$D = \frac{CP}{1000}$$

where D is the deposition in nc/m^2, C is the concentration in pc/liter, and P is the depth of precipitation in mm. The individual values of deposition and depth of precipitation are totalled for the month, and the average concentration for the month, $\overline{C}$, is determined by:

$$\overline{C} = \frac{\Sigma D}{\Sigma P} \times 1000$$

The January 1964 average concentrations and total depositions are given in table 2.

Table 1.—GROSS BETA ACTIVITY IN SURFACE AIR, JANUARY 1964

[Concentrations in pc/m³]

Station location		Number of samples	Maximum	Minimum	Average [a]
Alaska:	Adak	30	0.80	<0.10	0.40
	Anchorage	30	1.2	0.23	0.61
	Attu	29	1.2	<0.10	0.47
	Fairbanks	0	—	—	—
	Juneau	25	0.64	0.10	0.29
	Kodiak	26	0.99	<0.10	0.38
	Nome	23	1.0	0.13	0.44
	Point Barrow	30	0.80	<0.10	0.41
	St. Paul Island	22	2.5	<0.10	0.55
Ariz:	Phoenix	28	2.5	0.70	1.7
Ark:	Little Rock	28	3.1	0.62	1.5
Calif:	Berkeley	21	1.6	0.24	0.6
	Los Angeles	22	2.7	0.30	1.5
Canal Zone:	Ancon	15	0.74	0.20	0.34
Colo:	Denver	25	4.6	0.49	1.5
Conn:	Hartford	30	1.6	0.20	0.74
Del:	Dover	15	1.7	0.15	0.91
D. C:	Washington	31	1.9	0.15	0.93
Fla:	Jacksonville	28	3.7	0.18	1.5
	Miami	30	4.7	0.38	1.7
Ga:	Atlanta	23	2.3	<0.10	0.91
Guam:	Agana	31	1.4	0.14	0.62
Hawaii:	Honolulu	30	1.7	<0.10	0.70
Idaho:	Boise	29	1.3	0.15	0.59
Ill:	Springfield	28	1.3	0.38	0.78
Ind:	Indianapolis	29	2.0	0.35	1.00
Iowa:	Iowa City	27	1.7	0.41	0.88
Kans:	Topeka	29	1.8	0.55	1.0
Ky:	Frankfort	28	2.4	0.35	1.1
La:	New Orleans	30	3.1	0.29	1.1
Maine:	Augusta	30	1.8	0.31	0.91
	Presque Isle	30	1.4	<0.10	0.78
Md:	Baltimore	21	1.4	0.12	0.77
	Rockville	20	2.9	0.30	1.4
Mass:	Lawrence	30	1.9	0.31	0.92
	Winchester	30	1.5	0.17	0.72
Mich:	Lansing	30	2.6	0.38	1.1
Minn:	Minneapolis	29	1.2	0.32	0.76
Miss:	Jackson	30	3.8	0.25	1.4
	Pascagoula	2	1.4	1.3	1.3
Mo:	Jefferson City	30	1.7	0.47	0.92
Mont:	Helena	30	1.8	0.11	0.73
Nebr:	Lincoln	21	1.5	0.53	0.88
Nev:	Las Vegas	24	2.7	0.58	1.6
N. H:	Concord	21	2.0	0.25	1.2
N. J:	Trenton	30	1.9	0.22	0.86
N. Mex:	Sante Fe	26	4.0	0.76	1.5
N. Y:	Albany	21	1.3	0.16	0.75
	Buffalo	29	2.5	0.16	0.96
	New York	28	1.7	0.24	0.77
N. C:	Gastonia	29	3.9	0.22	1.2
N. Dak:	Bismarck	28	1.7	0.32	0.81
Ohio:	Cincinnati	22	2.2	0.24	1.0
	Columbus	26	2.1	0.26	1.1
	Painesville	31	3.0	0.40	1.4
Okla:	Oklahoma	26	1.9	0.42	1.1
	Ponca City	30	1.0	0.12	0.59
Ore:	Portland	21	3.0	0.28	0.86
Pa:	Harrisburg	29	1.8	0.13	0.63
P. R:	San Juan	23	2.1	<0.10	0.66
R. I:	Providence	29	1.9	0.26	0.79
S. C:	Columbia	30	3.9	<0.10	1.1
S. Dak:	Pierre	31	1.6	0.31	0.78
Tenn:	Nashville	30	2.4	0.17	1.1
Tex:	Austin	30	3.0	0.47	1.6
	El Paso	30	3.2	0.62	1.4
Utah:	Salt Lake City	31	2.6	0.40	1.1
Vt:	Barre	28	3.3	0.13	1.0
Va:	Richmond	28	1.2	0.17	0.67
Wash:	Seattle	30	0.74	0.11	0.35
W. Va:	Charleston	29	1.6	0.36	1.0
Wisc:	Madison	29	1.7	0.43	0.95
Wyo:	Cheyenne	28	3.8	0.32	1.2
Network summary		1,932	4.7	<0.10	0.94

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed before the average.

Table 2.—GROSS BETA ACTIVITY IN PRECIPITATION, JANUARY 1964

Station location		Average concentration [a] (pc/liter)	Total deposition [a] (nc/m²)
Alaska:			
	Anchorage	220	1.6
	Fairbanks	[b]—	—
	Juneau	340	51.0
Ark:	Little Rock	410	10.8
Calif:	Berkeley	220	25.3
	Los Angeles	200	9.4
Colo:	Denver	300	1.3
Conn:	Hartford	320	23.8
D. C:	Washington	330	26.0
Fla:	Jacksonville	<200	<30.8
	Miami	<200	<3.0
Ga:	Atlanta	—	—
Hawaii:	Honolulu	230	21.5
Idaho:	Boise	—	—
Ill:	Springfield	—	—
Ind:	Indianapolis	390	12.3
Iowa:	Iowa City	1,000	6.1
Kans:	Topeka	—	—
Ky:	Frankfort	360	12.6
La:	New Orleans	240	6.7
Maine:	Augusta	250	29.8
	Presque Isle	—	—
Md:	Baltimore	500	26.6
Mass:	Lawrence	400	50.9
	Winchester	510	38.9
Mich:	Lansing	670	18.2
Minn:	Minneapolis	670	5.6
Miss:	Jackson	290	34.7
Mo:	Jefferson City	350	5.5
Mont:	Helena	460	3.0
Nebr:	Lincoln	—	—
Nev:	Las Vegas	—	—
N. J:	Trenton	500	11.2
N. Mex:	Santa Fe	620	3.9
N. Y:	Albany	230	15.2
N. C:	Gastonia	220	26.8
N. Dak:	Bismarck	280	3.7
Ohio:			
	Columbus	370	15.7
	Painesville	3,700	152.4
Okla:	Oklahoma City	—	—
	Ponca City	430	7.7
Ore:	Portland	230	24.2
Pa:	Harrisburg	260	10.8
P. R:	San Juan	200	6.4
R. I:	Providence	350	30.2
S. C:	Columbia	260	53.1
S. Dak:	Pierre	—	—
Tenn:	Nashville	500	36.3
Tex:	Austin	—	—
	El Paso	1,200	3.6
Utah:	Salt Lake City	460	11.1
Vt:	Barre	340	27.2
Va:	Richmond	300	26.2
Wash:	Seattle	280	33.2
W. Va:	Charleston	250	15.6
Wisc:	Madison	520	9.9
Wyo:	Cheyenne	—	—

[a] The minimum concentration reported for a single sample is 200 pc/liter. If the individual sample has a concentration of <200 pc/liter, the deposition for that sample is calculated by $D=\frac{C\times P}{1000}=<0.2P$ in nc/m² (see text). A less-than sign (<) is used with the monthly total deposition whenever the sum of the individual less-than values represents more than 10 percent of the total. The monthly average concentration is then calculated as described in text, retaining the less-than sign when used with the total deposition.

[b] Dash indicates no evaporated sample received.

2. Canadian Air Monitoring Program,[3] January 1964

Department of National Health and Welfare

As part of its Radioactive Fallout Study Program, the Radiation Protection Division of the Canadian Department of National Health and Welfare monitors air and precipitation. Twenty-four collection stations are located at airports (see figure 2), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*3–7*).

Air

Each air sample involves the collection of particulates from about 650 cubic meters of air drawn through a high-efficiency 4-inch-diameter filter during a 24-hour period. These filters are sent daily to the Radiation Protection Division Laboratory in Ottawa. At the laboratory, a 2-inch-diameter disk is cut from each filter and counted with a thin-end-window, gas flow Geiger-Mueller counter system, calibrated with a Sr^{90}–Y^{90} standard. Four successive measurements are made on each filter to permit correction for natural activities and for the decay of short-lived fission products. The results are extrapolated to the end of the sampling period. Canadian air data for January 1964 are given in table 3 and presented in conjunction with U. S. and Mexican data by an isogram map (figure 4).

[3] Data from *Radiation Protection Programs, 2*:11-24, Radiation Protection Division, Canadian Department of National Health and Welfare (February 1964).

TABLE 3.—GROSS BETA ACTIVITY IN AIR, CANADA, JANUARY 1964

[Average concentrations in pc/m^3]

Station	Number of samples	Maximum	Minimum	Average
Calgary	30	2.8	0.3	0.8
Coral Harbour	31	2.1	0.3	1.1
Edmonton	31	1.6	0.2	0.7
Ft. Churchill	31	2.5	0.4	1.0
Ft. William	31	1.9	0.3	1.0
Fredericton	31	1.9	0.0	1.0
Goose Bay	31	1.7	0.5	1.1
Halifax	24	3.6	0.3	1.3
Inuvik	30	1.6	0.6	1.0
Montreal	31	2.2	0.2	1.0
Moosonee	31	1.8	0.6	1.3
Ottawa	28	1.9	0.3	0.9
Quebec	31	2.0	0.3	1.0
Regina	31	2.5	0.4	0.8
Resolute	31	1.9	0.1	0.8
St. John's, Nfld	29	2.6	0.1	1.0
Saskatoon	30	3.0	0.2	0.9
Sault Ste. Marie	31	1.5	0.1	0.8
Toronto	31	0.6	0.1	0.3
Vancouver	31	1.8	0.1	0.5
Whitehorse	31	1.1	0.1	0.5
Windsor	29	2.1	0.4	1.1
Winnipeg	31	1.5	0.3	0.9
Yellowknife	31	1.5	0.4	0.8
Network summary	727	3.6	0.0	0.9

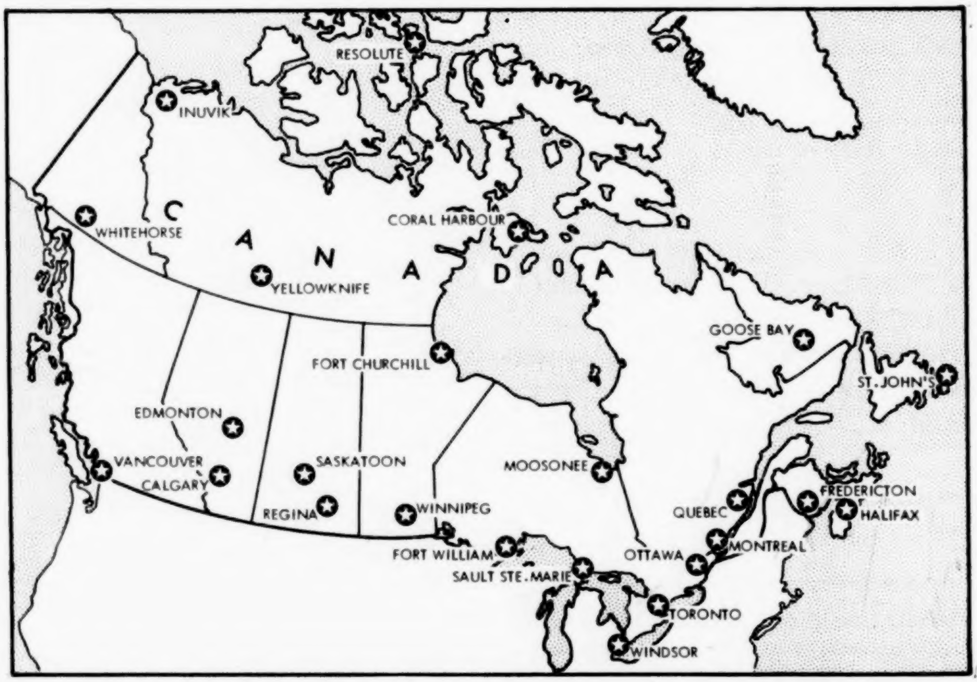

FIGURE 2.—CANADIAN AIR AND PRECIPITATION STATIONS, JANUARY 1964

Precipitation

The amount of radioactive fallout deposited on the ground is determined from measurements on material collected in special polyethylene-lined rainfall pots. The collection period for each sample is one month. After transfer of the water to the sample container, the polyethylene liner is removed, packed with the sample, and sent to the laboratory.

Strontium and cesium carriers are added to all samples on arrival at the laboratory. Other carriers are also added to selected samples according to the specific radionuclides to be determined. The samples are then filtered and the filtrate evaporated to near dryness. The filter paper containing insoluble matter is ignited together with the polyethylene liner at 450° C. The ash is combined with the soluble fraction, transferred to a glass planchet, evaporated under an infra-red lamp and then counted with a thin-end-window Geiger-Mueller counter calibrated with a Sr^{90}–Y^{90} source. Gross beta activities for January 1964 are given in table 4. Radionuclide analyses appear on page 206.

TABLE 4.—GROSS BETA ACTIVITY IN PRECIPITATION, CANADA, JANUARY 1964

Station	Total beta activity	
	pc/liter	nc/m²
Calgary	491	2.9
Coral Harbour	1307	8.3
Edmonton	288	5.2
Ft. Churchill	243	2.9
Ft. William	903	26.8
Fredericton	470	26.1
Goose Bay	325	12.7
Halifax	303	42.2
Inuvik	195	4.2
Montreal	368	40.7
Moosonee	287	18.2
Ottawa	227	14.8
Quebec	276	41.2
Regina	288	3.2
Resolute	898	22.8
St. John's, Nfld	339	43.5
Saskatoon	416	6.4
Sault Ste. Marie	267	29.2
Toronto	394	23.2
Vancouver	354	75.1
Whitehorse	219	3.7
Windsor	402	27.4
Winnipeg	340	5.7
Yellowknife	317	3.6
Average	413	20.4

3. Mexican Air Monitoring Program, January 1964

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comision Nacional de Energia Nuclear (CNEN) through its Radiological Protection Program (RPP) in 1961. The network consists of 17 stations (see figure 3), 12 of which are located at airports and operated by airline personnel. The remaining five stations are located at Mexico City, Mérida, Veracruz, San Luis Potosí and Ensenada. Staff members of the RPP operate the station at Mexico City while the other four stations are manned by members of the Centro de Prevision del Golfo de Mexico, the Chemistry Department of the University of Merida, the Instituto de Zonas Deserticas of the University of San Luis Potosi, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air for 24 hours a day, 3 or 4 days a week, at the rate of approximately 1,200 cubic meters per day, through a high-efficiency, 6 x 8-inch glass fiber filter, using high volume samplers. After each 24-hour sampling period, the filter is removed and forwarded via air mail to the "Laboratorio de Estudios Sobre Contaminación Radiactiva", CNEN, in Mexico City for assay of gross beta activity. A minimum of 3 or 4 days after collection is allowed for decay of naturally occurring radon and thoron daughters. Data are not extrapolated to time of collection.

The maximum, minimum and average fission product beta concentrations in surface air during January 1964 are presented in table 5. The data are also represented in the beta activity isogram map of North America, figure 4.

TABLE 5.—GROSS BETA ACTIVITY OF AIRBORNE PARTICULATES, MEXICO, JANUARY 1964

[Concentrations in pc/m³]

Station	Number of samples	Maximum	Minimum	Average
Acapulco [a]	2	0.2	0.1	—
Ciudad Juárez	21	3.3	0.5	1.2
Chihuahua	23	3.7	0.8	1.8
Ensenada	8	2.7	0.3	1.5
Guadalajara	15	0.8	0.1	0.2
Guaymas [a]	0	—	—	—
La Paz	21	3.0	0.4	1.8
Matamoros [a]	2	0.6	0.5	—
Mazatlán [a]	0	—	—	—
Mérida	11	1.8	0.2	0.7
Mexico City	22	0.9	0.1	0.2
Nuevo Laredo	4	1.8	0.8	1.2
San Luis Potosí	4	0.4	0.1	0.3
Tampico	9	1.4	0.4	0.6
Torreón	12	3.6	0.6	1.5
Tuxtla Gutiérrez [a]	0	—	—	—
Veracruz [a]	—	—	—	—

[a] Equipment out of order.

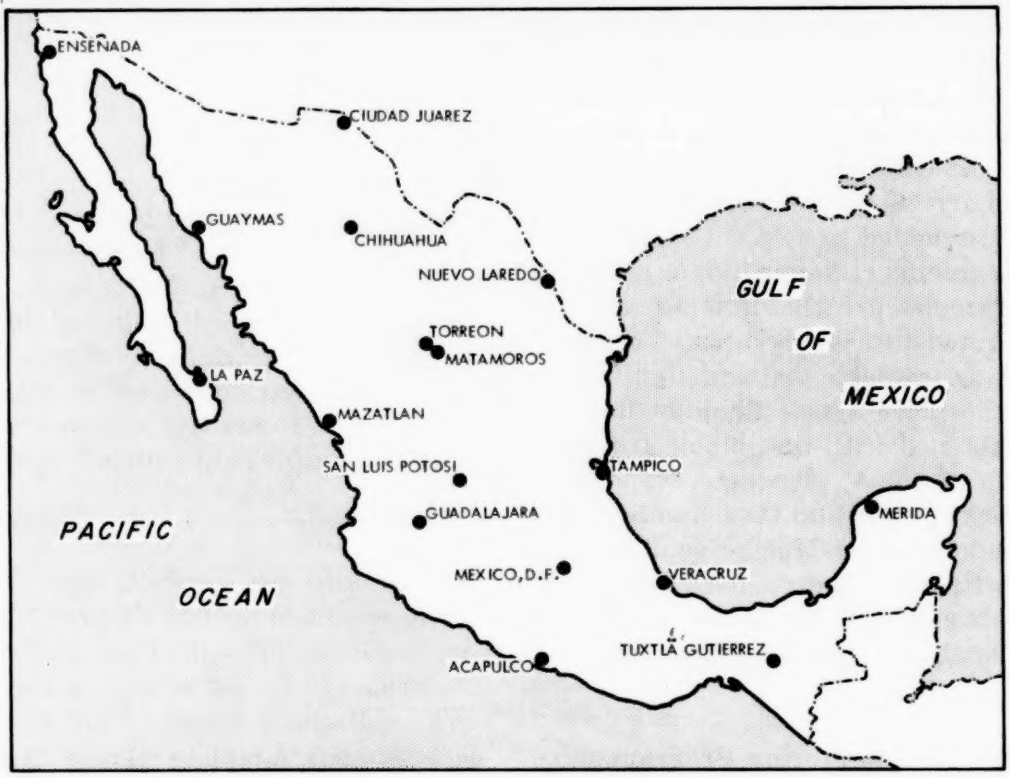

FIGURE 3.—FALLOUT NETWORK SAMPLING STATIONS IN MEXICO

4. Pan American Air Sampling Program January 1964

Pan American Health Organization and Public Health Service

Gross beta activity in air is monitored by three countries in South America under the auspices of a collaborative program developed by the Pan American Health Organization and the Public Health Service (PHS) for assisting countries of the Americas in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network.

The three air sampling stations included in the program are operated by the technical staff of the Ministry of Health in each country. The station in Santiago, Chile is operated by the Occupational Health Service; in Lima, Peru by the Institute of Occupational Health; and in Caracas, Venezuela by the Venezuelan Institute for Scientific Investigations. The Caracas station began operation in November 1962 and the other two stations were started the following month.

The January 1964 air monitoring results from the three participating countries are given in table 6. The Caracas station is shown on the gross beta concentration isogram map (figure 4). The January average at this station, adjusted by the RSN intercalibration factor[4] is 0.35 pc/m^3, which is below the lowest isogram used on the map (0.5 pc/m^3).

[4] The RSN factor is 1.28 (see page 1-14).

TABLE 6.—GROSS BETA ACTIVITY IN AIR, JANUARY 1964

[Concentrations in pc/m^3]

Sampling stations	No. of samples	Maximum	Minimum	Average [a]
Caracas, Venezuela	20	0.49	<0.10	0.27
Lima, Peru	0	—	—	—
Santiago, Chile	16	0.26	<0.10	<0.12

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed in front of the average.

5. Gross Beta Activity in Air, North America, January 1964

Beginning with January 1963 data, monthly average concentrations of airborne gross beta activity in Canada and the United States have been presented in combined form as isogram maps of most of North America.[a] The data from the Radiation Surveillance Network and the Canadian Air Network were adjusted to each other by means of an intercalibration factor derived by Lockhart and Patterson (*8*).

With the formation of the Mexican Air monitoring program, new intercalibration ratios were determined, this time including the Canadian Network, Radiation Surveillance Network, National Air Sampling Network, the new 80th Meridian Network, and the Mexican Network (*9*). The new intercalibration factors include some changes in standardization in both the RSN and the Canadian Air Network, effective September 1963. The intercalibration factors are, therefore, not the same as were previously used.

Figure 4 shows the January 1964 activity in air throughout North America based on the data from the Canadian Air Monitoring Program, the Radiation Surveillance Network and Mexican Air Monitoring program. An intercalibration factor of 1.28 was applied to the RSN data and the Mexican data were multiplied by 0.81 in order to adjust them to Canadian data.

[a] The January through December 1963 isogram maps were published in the May 1963 through April 1964 issues of *Radiological Health Data*.

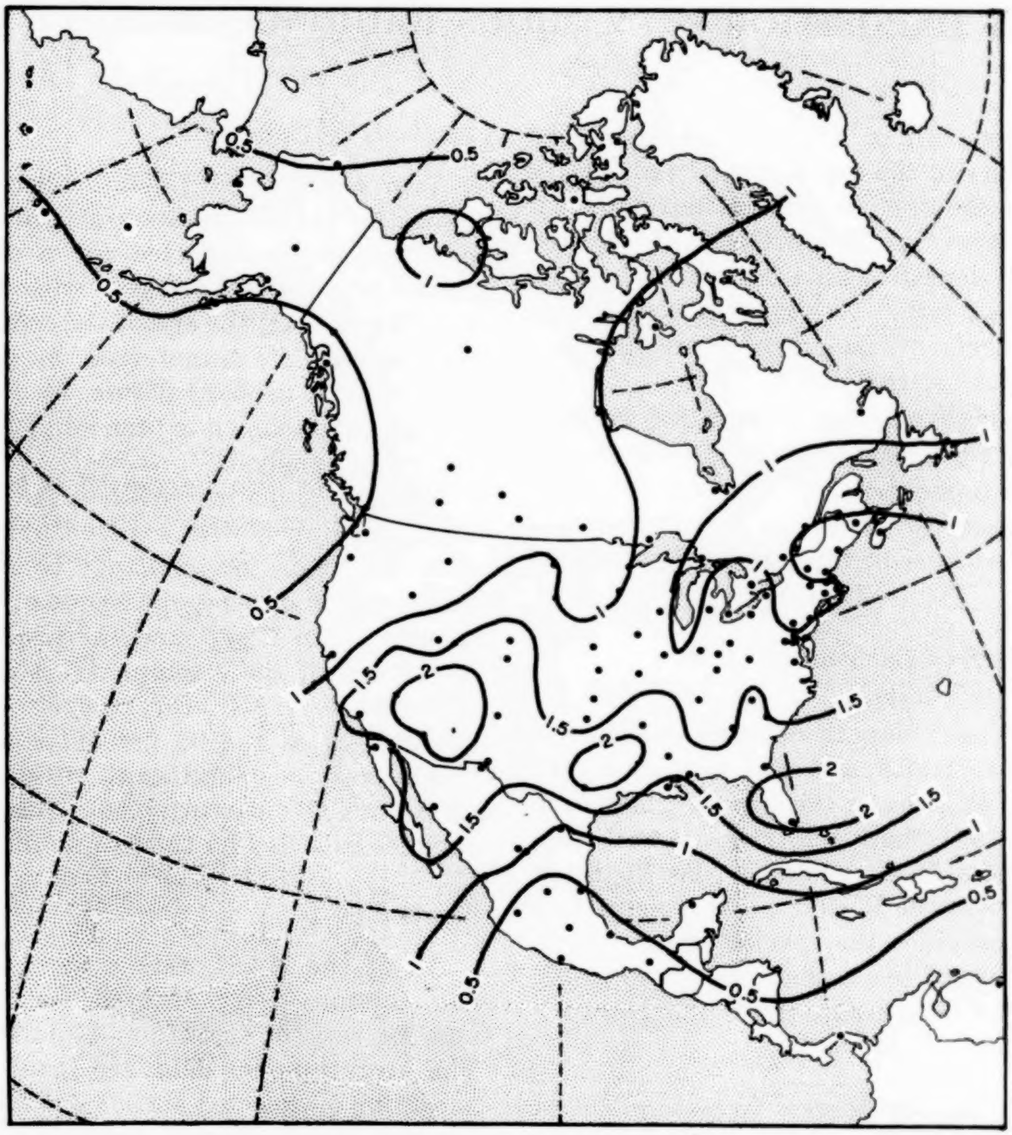

FIGURE 4.—ISOGRAMS OF AVERAGE GROSS BETA CONCENTRATIONS IN AIR THROUGHOUT NORTH AMERICA, JANUARY 1964

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MONTHLY DEPOSITION OF VARIOUS RADIONUCLIDES

For the purpose of this section the word "fallout" refers to the deposition of radioactive materials on the earth's surface, normally expressed in terms of the activity of selected radionuclides deposited on a unit area during a given period of time. Unless otherwise stated, fallout measurements include both precipitation and dry fallout (settled dust).

Reports of fallout measurements at selected stations in North and South America are presented below.

Fallout in the United States and Other Areas,[1] April—June 1963

Health and Safety Laboratory Atomic Energy Commission

Monthly fallout deposition rates are determined by the Health and Safety Laboratory (HASL) for 48 sites in the United States and 104 locations in other countries. HASL data from 10 of the U. S. stations and 21 other selected points in the Western Hemisphere (see figure 1) covering the period from April through June 1963 are summarized below. All of the stations of the 80th Meridian Network are represented.

[1] The data in this article were taken from *Fallout Program Quarterly Summary Report, HASL-144*: 2-172, Health and Safety Laboratory, AEC, New York, N.Y. 10014.

Methods of Collection

Two methods of fallout collection are employed by HASL. In the first, precipitation and dry fallout are collected for a period of one month in stainless steel pots with exposed areas of $0.076/m^2$. At the end of the collection period, the contents are transferred, by careful scrubbing with a rubber spatula, to a polyethylene sample bottle which is then shipped to the laboratory for analysis.

The second method involves the use of a polyethylene funnel, with exposed area of $0.072m^2$ attached to an ion exchange column. After a one-month collection, the inside of the funnel is wiped with a tissue, and the tissue is inserted in the end of the column, which is then sealed and sent to HASL for analysis. It has been shown that at the 95 percent confidence level there was no significant difference in the strontium-90 measurements obtained from samples collected by the two methods (*1*).

Strontium-90

All of the HASL fallout samples—both pot and column—were assayed for strontium-90 and the ratio of strontium-89 to strontium-90. The strontium-90 data are given in tables 1 and 2 for 58 selected stations. Where duplicate samples were collected, the average values are given.

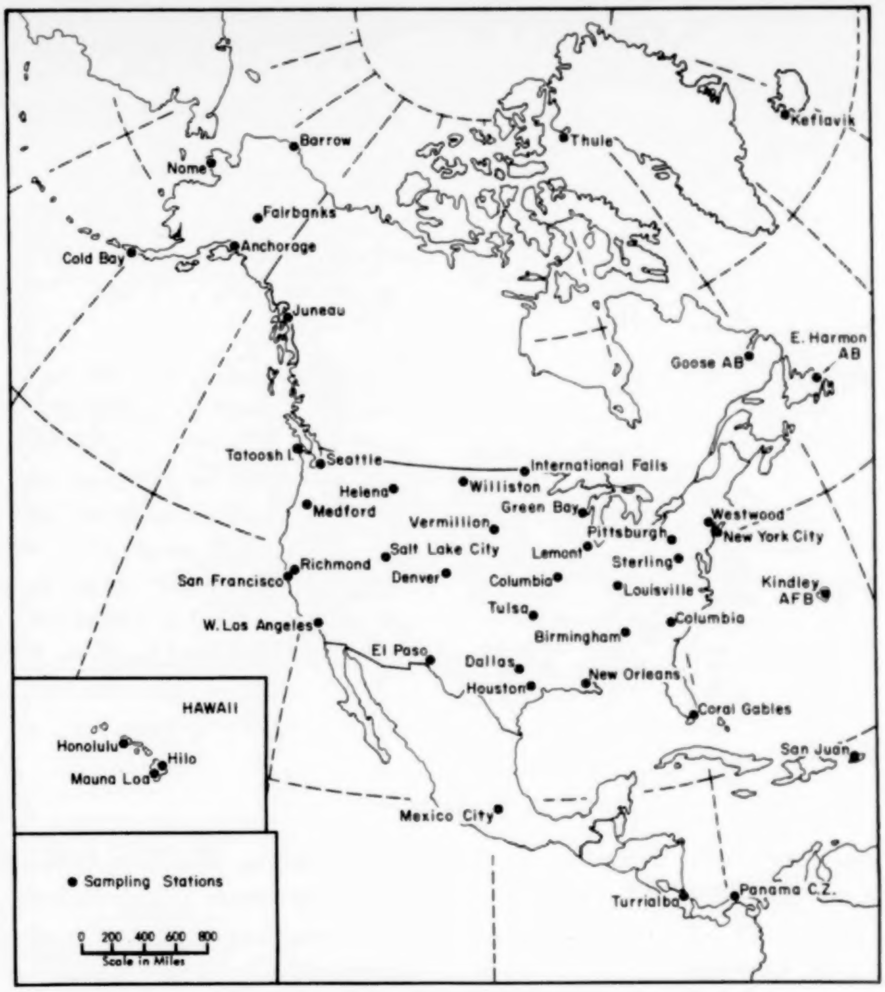

Figure 1.—HASL FALLOUT SAMPLING LOCATIONS

Other Radionuclides

Laboratories at Richmond, California; Westwood, New Jersey; Pittsburgh, Pennsylvania; and Houston, Texas have analyzed duplicate monthly pot samples for various radionuclides. The monthly deposition rates for Zr^{95} and Cs^{137}, as well as the Sr^{89}/Sr^{90} ratio and precipitation depth, are presented in table 3. The strontium-90 values for these stations are included in table 1.

Table 1.—MONTHLY STRONTIUM-90 FALLOUT IN THE UNITED STATES, HASL, APRIL–JUNE 1963

[Deposition in nc/m²]

Sampling location and type of collection		April	May	June
Ala:	Birmingham (pot)	5.19	2.70	3.04
Alaska:	Anchorage (col)	0.78	0.65	1.38
	Barrow (col)	[a]—	—	—
	Cold Bay (col)	1.20	1.04	1.06
	Fairbanks (col)	0.40	0.30	2.43
	Juneau (col)	0.70	1.13	2.80
	Nome (col)	—	—	—
Calif:	Los Angeles (pot)	1.58	0.23	0.59
	Palo Alto (col)	1.52	0.69	0.16
	Palo Alto (pot)	1.85	0.83	0.11
	Richmond (pot)	2.61	0.41	0.1
	San Francisco (col)	1.50	0.34	1.18
Colo:	Denver (col)	0.15	1.64	4.05
Fla:	Coral Gables (pot)	3.63	2.35	2.38
Hawaii:	Hilo (col)	0.33	6.17	4.83
	Mauna Loa (col)	0.31	1.42	0.76
	Oahu (pot)	2.97	1.19	3.75
Ill:	Lemont (pot)	1.39	1.76	3.83
Ky:	Louisville (pot)	1.53	5.80	4.02
La:	New Orleans (col)	0.88	1.05	1.18
Minn:	International Falls (col)	5.10	5.05	1.88
Mo:	Columbia (col)	1.97	1.14	1.93
Mont:	Helena (col)	1.22	1.52	4.36
N. J:	Westwood (col)	2.87	3.71	1.82
	Westwood (pot)	3.01	3.80	2.43
N. Y:	New York (pot)	1.43	1.75	1.82
N. Dak:	Williston (col)	0.89	0.87	3.94
Okla:	Tulsa (pot)	1.81	2.56	0.69
Ore:	Medford (col)	1.61	1.90	1.01
Pa:	Pittsburgh (col)	2.72	2.18	—
	Pittsburgh (pot)	3.05	2.20	—
S. C:	Columbia (col)	2.98	1.18	2.50
S. Dak:	Vermillion (pot)	2.92	2.96	5.05
Tex:	Dallas (col)	2.25	1.37	0.20
	El Paso (col)	0.10	0.51	0.21
	Houston (col)	0.01	0.26	2.17
	Houston (pot)	0.83	0.97	2.75
Va:	Sterling (col)	2.38	0.85	1.59
Utah:	Salt Lake City (pot)	7.82	0.80	4.78
Wash:	Seattle (pot)	2.06	0.52	2.11
	Tatoosh I. (col)	2.75	1.26	1.13
Wis:	Green Bay (col)	1.32	1.68	2.64

[a] Dash indicates no sample received.

Table 2.—MONTHLY STRONTIUM-90 FALLOUT IN NORTH AND SOUTH AMERICA, HASL, APRIL–JUNE 1963

[Deposition in nc/m²]

Station	Collection period, 1963		
	April	May	June
Greenland, Thule	0.02	0.07	0.20
Iceland, Keflavik	1.71	0.93	1.77
Canada, Goose AB	0.49	1.51	6.29
Moosonee [a]	1.46	3.10	3.55
Bermuda	0.33	0.09	0.27
Puerto Rico, San Juan	0.93	0.84	0.84
Mexico, Mexico City	0.91	0.16	1.56
Costa Rica, Turrialba	0.93	0.48	0.02
Canal Zone	0.86	1.59	0.58
Venezuela, Caracas	0.22	0.77	0.08
Colombia, Bogota	0.14	0.05	0.02
Equador, Quito	0.03	0.02	not received
Guayaquil [a]	0.04	0.01	0.03
Brazil, Recife	0.03	0.05	0.07
Peru, Lima [a]	0.01	0.01	0.01
Bolivia, La Paz	0.01	0.02	0.03
Chacaltaya [a]	[b]—	0.03	0.12
Chile, Antofagasta [a]	0.01	0.01	0.02
Santiago [a]	0.01	0.05	0.10
Puerto Montt [a]	0.37	0.30	0.37
Punta Arenas [a]	0.09	0.08	0.08

[a] 80th Meridian Network station. [b] Sample not received.

Table 3.—RADIOCHEMICAL ANALYSES OF POT FALLOUT SAMPLES, HASL, APRIL–JUNE 1963

[Deposition in nc/m²]

Location and analyses	Collection period, 1963		
	April	May	June
California, Richmond			
Precipitation (mm)	109	15	dry
Sr^{89}/Sr^{90} ratio	9.0	6.2	2.2
Zr^{95} (nc/m²)	54.6	10.9	2.0
Cs^{137} (nc/m²)	4.4	0.64	0.17
New Jersey, Westwood			
Precipitation (mm)	24	64	90
Sr^{89}/Sr^{90} ratio	7.6	5.3	3.6
Zr^{95} (nc/m²)	40.2	51.8	23.9
Cs^{137} (nc/m²)	4.4	5.9	3.7
Pennsylvania, Pittsburgh			
Precipitation (mm)	77	42	
Sr^{89}/Sr^{90} ratio	9	7	
Zr^{95} (nc/m²)	38.6	21.2	
Cs^{137} (nc/m²)	5.7	4.0	
Texas, Houston			
Precipitation (mm)	23	16	—
Sr^{89}/Sr^{90} ratio	5.8	6.6	0.2
Zr^{95} (nc/m²)	20.1	16.0	17.5
Cs^{137} (nc/m²)	8.2	20.1	5.4

Fallout Measurements in Canada, October—December 1963

Department of National Health and Welfare Ottawa, Canada

The monthly accumulated precipitation samples collected in conjunction with the Canadian air sampling network described earlier in this issue represent total fallout (wet and dry), since they are collected in deep pots lined with polyethylene. The radiochemical analyses of these samples for October through December 1963 are given in table 4.

Table 4.—ANALYSIS FOR SPECIFIC RADIONUCLIDES IN CANADIAN FALLOUT, OCTOBER–DECEMBER 1963

[Deposition in nc/m²]

Station	October					November					December				
	Sr^{89}	Sr^{90}	Cs^{137}	Zr^{95}	Ba^{140}	Sr^{89}	Sr^{90}	Cs^{137}	Zr^{95}	Ba^{140}	Sr^{89}	Sr^{90}	Cs^{137}	Zr^{95}	Ba^{140}
Calgary	0.10	0.10	0.21	0.47	0.01	0.06	0.14	0.45	0.63	0.01	0.00	0.09	0.46	0.47	0.07
Coral Harbour	0.13	0.52	0.99	[a]—	—	0.07	0.14	0.29	—	—	0.07	0.25	0.52	—	—
Edmonton	0.55	0.51	0.44	—	—	0.00	0.14	0.28	—	—	0.06	0.17	—	—	—
Ft. Churchill	0.26	0.22	0.37	—	—	0.06	0.09	0.14	—	—	0.00	0.18	0.26	—	—
Ft. William	0.35	0.49	0.86	—	—	0.19	0.36	1.28	—	—	0.05	0.23	0.33	—	—
Fredericton	0.63	0.81	1.69	—	—	0.64	1.07	1.80	—	—	0.00	0.16	—	—	—
Goose Bay	0.69	0.62	1.46	—	—	0.35	0.57	0.99	—	—	0.06	0.26	0.41	—	—
Halifax	0.61	0.86	1.43	2.42	0.02	0.91	1.35	2.64	2.93	0.04	0.39	0.76	1.47	0.59	0.01
Inuvik	0.48	0.41	0.77	—	—	0.09	0.09	0.29	—	—	0.00	0.15	0.29	—	—
Montreal	0.29	0.30	0.85	1.40	0.03	—	—	—	—	—	0.08	0.19	0.35	0.35	0.02
Moosonee	0.55	0.72	0.99	—	—	0.31	0.58	1.09	—	—	0.00	0.25	0.44	—	—
Ottawa	0.50	0.45	0.93	—	—	0.55	0.99	1.60	—	—	0.08	0.20	0.44	—	—
Quebec	1.51	1.51	2.84	—	—	0.56	0.93	2.24	—	—	0.21	0.72	1.88	—	—
Regina	0.10	0.79	0.61	—	—	0.07	0.13	0.33	—	—	0.04	0.06	0.19	—	—
Resolute	0.57	0.55	0.76	—	—	0.18	1.09	0.82	—	—	0.29	0.53	1.12	—	—
St. John's, Nfld	0.81	0.86	2.38	—	—	—	—	—	—	—	0.46	1.17	1.94	—	—
Saskatoon	0.22	0.29	0.76	—	—	0.08	0.20	0.40	—	—	0.00	0.16	0.17	—	—
Sault Ste. Marie	[b]	[b]	[b]	[b]	[b]	0.44	1.04	1.40	—	—	0.15	0.44	0.50	—	—
Toronto	0.16	0.20	0.18	—	—	0.28	0.53	0.93	—	—	0.08	0.29	0.65	—	—
Vancouver	1.68	2.02	3.88	5.95	0.06	0.25	0.58	1.22	1.75	0.20	1.10	2.10	3.86	2.11	0.06
Whitehorse	0.10	0.10	0.22	—	—	—	—	—	—	—	0.00	0.00	0.22	—	—
Windsor	0.32	0.51	0.84	—	—	0.37	0.54	0.37	—	—	0.21	0.20	0.60	—	—
Winnipeg	0.45	0.58	1.99	2.08	0.02	0.13	0.23	0.50	0.22	0.01	0.07	0.13	0.49	0.22	0.02
Yellowknife	0.62	0.75	0.79	—	—	0.19	0.21	1.09	—	—	0.04	0.05	0.11	—	—

[a] Dash indicates no analysis. [b] No sample received.

Table 5.—STRONTIUM-90 DEPOSITION IN CANADA, 1963 SUMMARY

[Monthly deposition in nc/m²]

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Calgary	0.25	0.13	0.23	1.10	0.97	6.77	5.41	1.87	0.40	0.10	0.14	0.09
Halifax (Shearwater)	0.51	[a]—	—	1.98	4.34	1.26	1.86	2.36	1.20	0.86	1.35	0.76
Montreal	0.25	0.87	1.42	2.98	2.68	3.20	—	4.38	1.97	0.30	—	0.19
Vancouver	0.47	1.80	1.38	2.54	0.36	0.89	2.04	0.92	0.82	2.02	0.58	2.10
Winnipeg	0.19	0.51	0.22	2.84	4.15	—	—	2.56	0.64	0.58	0.23	0.13

[a] Dash indicates no analyses.

A 1963 summary of the strontium–90 deposition for five stations is given in table 5. Radiochemical analyses of fallout samples for these five stations for the months of October 1962 through April 1963 were included with the tables of gross beta in precipitation in the February through August 1963 issues of *RHD*. May and June radiochemical data for 23 stations were reported in the October 1963 *RHD*, and July through August data for the full 24 station networks were given in the January 1964 *RHD*.

REFERENCE

(*1*) Ong, L. D. Y., Homogeneity Between Pot and Ion Exchange Column Strontium-90 Measurements, *Fallout Program Quarterly Summary Report, HASL-135:* 256-69, Office of Technical Services, Department of Commerce, Washington 25, D. C. (April 1, 1963), price $4.00.

Section II—Milk and Food

MILK SURVEILLANCE

Although milk is only one of the many sources of dietary intake of radionuclides, it is the single food item most often used as an indicator of the population's intake of radionuclides from the environment. This is because fresh milk is consumed by a large segment of the United States population and contains most of the radionuclides occurring in the environment which have been identified as being biologically important. In addition, milk is produced and consumed on a regular basis, is convenient to handle, is easily analyzed, and samples which are representative of milk consumption in any area can be readily obtained.

1. Pasteurized Milk Network, January 1964

Division of Radiological Health and Division of Environmental Engineering and Food Protection, Public Health Service

The Public Health Service pasteurized milk radionuclide surveillance program had its origin in a raw milk monitoring network (*1*) established by the Service in 1957. One of the primary objectives of this network was the development of methods for milk collection and radiochemical analysis suitable for larger scale programs.

Experience derived from this earlier network led to the activation of a pasteurized milk sampling program with stations selected to provide nationwide surveillance of milk production and consumption areas. The present network, which consists of 63 stations, has at least one station in every State, the Canal Zone, and Puerto Rico.

Through the cooperation of State and local milk sanitation authorities, samples are routinely collected at each of these stations. Composites of the samples are preserved with formaldehyde and are sent to the PHS Southwestern (SWRHL), Southeastern (SERHL), or Northeastern Radiological Health Laboratories (NERHL) for analysis. Gamma analyses for iodine-131 are made within 3 to 6 days after sample collection, and any results exceeding 100 pc/liter are immediately telephoned to State health officials for possible public health action. Analytical results are normally available 6 to 7 weeks after collection; publication in *RHD* follows 3 to 4 months after sample collection.

Sampling and Compositing Procedures

The method specifies that each station's sample be composited of subsamples from each milk processing plant in proportion to the plant's average sales in the community served. At most stations the composite sample represents from 80 to 100 percent of the milk processed. Prior to September 15, 1961, the composite sample was taken from one day's sales per month and was as representative of the community's supply as could be achieved under practical conditions. Beginning with the resumption of nuclear weapons testing in the atmosphere in September 1961, and continuing through January

1963, samples were collected twice a week at nearly all stations and daily for short periods at selected stations. Since then, the sampling frequency has been reduced to once a week.

Analytical Errors

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintillation spectroscopy.[1] After gamma scanning, samples from two consecutive weeks are composited and analyzed radiochemically for strontium–89 and strontium–90. There is an inherent statistical variation associated with all measurements of radionuclide concentrations. With the low radionuclide levels which are usually found in milk and other environmental samples, this variation on a percentage basis is relatively high. The variation is dependent upon such factors as the method of chemical analysis, the sample counting rate and counting time, interferences from other radionuclides, and the background count. For milk samples, counting times of 50 minutes for gamma spectroscopy and 30 to 50 minutes for low background beta determinations are used. Table 1 shows the approximate total analytical error (including counting error) associated with radionuclide concentrations in milk. The $\pm 2\sigma$ range about the measured concentration corresponds to a 95 percent certainty that the true concentration is within this range. The minimum detectable concentration is defined as the measured concentration at which the two-standard-deviation analytical error is equal to the measurement. Accordingly, the minimum detectable concentrations in units of pc/liter are Sr^{89}, 5; Sr^{90}, 2; Cs^{137}, 10; Ba^{140}, 10; and I^{131}, 10. At these levels and below, the counting error constitutes nearly all of the analytical error.

Calcium analyses at SERHL are done by an ion exchange and permanganate titration method while at NERHL and SWRHL an ethylenediaminetetraacetic acid (EDTA) method is used. Stable potassium concentrations are estimated from the potassium–40 concentrations determined from the gamma spectrum.

[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium-140 analysis.

TABLE 1.—ANALYTICAL ERRORS ASSOCIATED WITH ESTIMATED CONCENTRATIONS FOR SELECTED RADIONUCLIDES IN MILK

Nuclide	Estimated concentration (pc/liter)	Error [a] (pc/liter)	Estimated concentration (pc/liter)	Error [a] (percent of concentration)
Iodine-131	0 to 100	±10	100 or greater	±10%
Barium-140	0 to 100	±10	100 or greater	±10%
Cesium-137	0 to 100	±10	100 or greater	±10%
Strontium-89	0 to 50	±5	50 or greater	±10%
Strontium-90	0 to 20	±2	20 or greater	±10%

[a] Two standard deviations.

Data Presentation

Table 2 presents summaries of the analyses for January 1964 (December 29, 1963—January 25, 1964). Although not shown in table 2, the iodine–131 and barium–140 monthly average concentrations in milk were less than 10 pc/liter. When a radionuclide is reported by a laboratory as being below the minimum detectable concentration, one-half the minimum detectable value is used as the best approximation in calculating the monthly average. Beginning with October 1963 data, however, zero is used as the best approximation to a nondetectable concentration of iodine–131 or barium–140. A similar procedure is used for the network average. Table 3 shows the distribution of the network's stations according to monthly average radionuclide concentrations in milk.

Figures 1, 2, and 3 are isogram maps showing the estimated strontium–89, strontium–90, and cesium–137 concentrations in milk over the entire country. The value printed beside each station is the monthly average concentration for that station. The isograms were developed by arbitrary interpolation between values for the individual stations. Additional modifications to the isograms are made according to available information on milksheds.

Continuing the practice followed in previous issues of *RHD*, the average monthly strontium–90 concentrations in pasteurized milk from 16 selected cities in the sampling program are presented in figure 4. Each graph shows the strontium–90 concentrations in milk from one city in each of the four U. S. Bureau of Census regions. This method of selection permits graphic presentation of data for each city in the network three times a year.

Table 2.—RADIOACTIVITY IN PASTEURIZED MILK, JANUARY 1964 [a]

[Average radioactivity concentrations in pc/liter]

Sampling locations		Calcium (g/liter) Fourth quarter	Calcium (g/liter) Avg. for month	Potassium (g/liter) Fourth quarter	Potassium (g/liter) Avg. for month	Strontium-89 Fourth quarter	Strontium-89 Avg. for month	Strontium-90 Fourth quarter	Strontium-90 Avg. for month	Cesium-137 Fourth quarter	Cesium-137 Avg. for month	Last Sr^{90} graph in *RHD* (1964)
Ala:	Montgomery	1.22	1.24	1.5	1.5	5	<5	21	22	85	95	February
Alaska:	Palmer	1.20	1.19	1.6	1.6	15	10	31	27	180	170	March
Ariz:	Phoenix	1.16	1.20	1.7	1.6	<5	<5	3	4	30	20	May
Ark:	Little Rock	1.20	1.19	1.5	1.4	10	<5	40	39	130	150	March
Calif:	Sacramento	1.22	1.27	1.6	1.6	<5	<5	8	11	60	60	April
	San Francisco	1.22	1.23	1.6	1.6	5	5	9	11	70	80	February
Canal Zone:	Cristobal	1.13	1.15	1.5	1.5	<5	<5	5	6	40	50	March
Colo:	Denver	1.19	1.25	1.6	1.7	15	<5	17	18	85	80	April
Conn:	Hartford	1.19	1.16	1.6	1.7	10	<5	25	24	170	180	April
Del:	Wilmington	1.21	1.21	1.7	1.5	5	<5	23	22	130	145	May
D. C:	Washington	1.17	1.20	1.5	1.6	10	<5	17	18	80	105	February
Fla:	Tampa	1.22	1.27	1.4	1.4	5	<5	16	14	250	185	May
Ga:	Atlanta	1.19	1.21	1.5	1.6	10	<5	29	30	120	145	February
Hawaii:	Honolulu	1.15	1.19	1.7	1.6	10	<5	11	9	85	80	March
Idaho:	Idaho Falls	1.19	1.19	1.6	1.7	15	10	26	31	170	200	May
Ill:	Chicago	1.18	1.17	1.7	1.6	10	<5	20	21	110	145	February
Ind:	Indianapolis	1.25	1.22	1.6	1.6	10	<5	22	22	100	120	April
Iowa:	Des Moines	1.18	1.22	1.5	1.5	15	5	25	27	100	110	May
Kans:	Wichita	1.16	1.19	1.6	1.6	10	10	18	22	65	75	March
Ky:	Louisville	1.16	1.20	1.5	1.6	15	5	30	31	100	125	May
La:	New Orleans	1.24	1.28	1.5	1.5	15	<5	44	48	135	155	March
Maine:	Portland	1.22	1.21	1.6	1.6	10	5	35	32	235	230	May
Md:	Baltimore	1.14	1.20	1.4	1.5	10	<5	20	19	105	110	May
Mass:	Boston	1.22	1.19	1.6	1.7	15	<5	36	35	250	265	February
Mich:	Detroit	1.20	1.17	1.6	1.6	5	<5	20	20	120	140	April
	Grand Rapids	1.23	1.22	1.6	1.5	5	<5	22	23	130	145	May
Minn:	Minneapolis	1.18	1.17	1.6	1.6	25	10	33	38	155	180	February
Miss:	Jackson	1.25	1.27	1.4	1.4	15	5	36	37	105	120	April
Mo:	Kansas City	1.17	1.20	1.5	1.5	15	<5	29	29	85	105	April
	St. Louis	1.20	1.23	1.6	1.5	15	10	21	22	85	105	March
Mont:	Helena	1.20	1.23	1.6	1.5	10	10	29	28	195	235	March
Nebr:	Omaha	1.20	1.19	1.6	1.5	25	10	25	23	95	100	May
Nev:	Las Vegas	1.14	1.30	1.7	1.7	<5	<5	10	19	80	95	February
N. H:	Manchester	1.24	1.23	1.6	1.7	10	<5	37	35	275	265	May
N. J:	Trenton	1.20	1.17	1.6	1.6	10	10	19	20	120	140	April
N. Mex:	Albuquerque	1.16	1.18	1.6	1.6	<5	<5	11	11	50	60	March
N. Y:	Buffalo	1.18	1.16	1.7	1.6	10	<5	23	21	145	165	April
	New York	1.20	1.15	1.7	1.6	15	<5	30	28	175	190	February
	Syracuse	1.19	1.18	1.7	1.6	10	<5	22	23	150	165	March
N. C:	Charlotte	1.19	1.24	1.5	1.4	15	<5	30	30	105	110	March
N. Dak:	Minot	1.18	1.18	1.6	1.6	40	10	55	68	145	165	May
Ohio:	Cincinnati	1.23	1.21	1.6	1.6	10	<5	23	24	90	130	April
	Cleveland	1.22	1.22	1.7	1.6	5	<5	22	22	105	130	March
Okla:	Oklahoma City	1.17	1.20	1.5	1.6	5	<5	21	22	70	85	February
Ore:	Portland	1.21	1.23	1.6	1.6	20	10	30	29	180	170	April
Pa:	Philadelphia	1.22	1.21	1.6	1.6	5	<5	21	20	120	140	March
	Pittsburgh	1.27	1.20	1.6	1.6	10	<5	29	30	145	160	March
P. R:	San Juan	1.16	1.18	1.5	1.6	5	<5	12	11	65	55	March
R. I:	Providence	1.21	1.18	1.6	1.6	5	<5	27	26	175	180	May
S. C:	Charleston	1.21	1.21	1.5	1.5	10	<5	27	33	120	120	April
S. Dak:	Rapid City	1.20	1.21	1.7	1.6	25	10	42	40	170	180	February
Tenn:	Chattanooga	1.23	1.26	1.5	1.6	15	10	35	35	120	140	February
	Memphis	1.22	1.25	1.5	1.5	10	<5	28	28	75	90	May
Tex:	Austin	1.18	1.20	1.5	1.6	<5	<5	8	8	40	40	February
	Dallas	1.20	1.23	1.5	1.6	5	<5	19	21	75	80	April
Utah:	Salt Lake City	1.19	1.25	1.6	1.6	15	5	26	28	170	200	March
Vt:	Burlington	1.21	1.18	1.6	1.7	10	<5	28	28	200	220	April
Va:	Norfolk	1.17	1.20	1.5	1.6	10	<5	21	20	90	100	April
Wash:	Seattle	1.21	1.20	1.6	1.6	15	<5	24	20	155	120	February
	Spokane	1.21	1.24	1.7	1.6	20	10	31	40	160	155	April
W. Va:	Charleston	1.17	1.19	1.4	1.6	15	<5	26	25	85	105	February
Wis:	Milwaukee	1.28	1.23	1.8	1.7	<5	<5	19	21	135	160	May
Wyo:	Laramie	1.18	1.21	1.6	1.5	15	10	20	19	115	105	May
Network average		1.20	1.21	1.6	1.6	11	<5	24.2	24.9	123	134	Nov. 63

[a] The monthly average iodine-131 and barium-140 concentration at each station was <10 pc/liter.

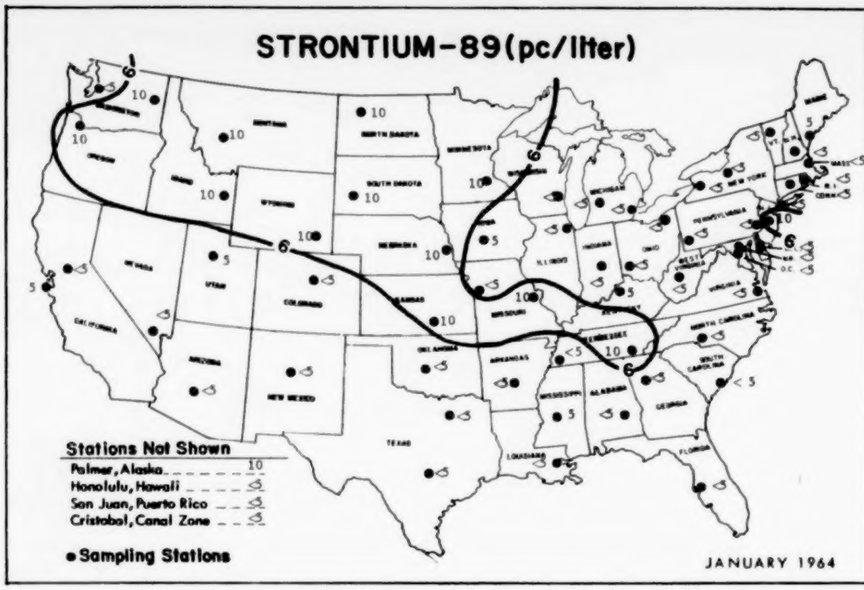

FIGURE 1.—STRONTIUM-89 CONCENTRATIONS IN PASTEURIZED MILK, JANUARY 1964

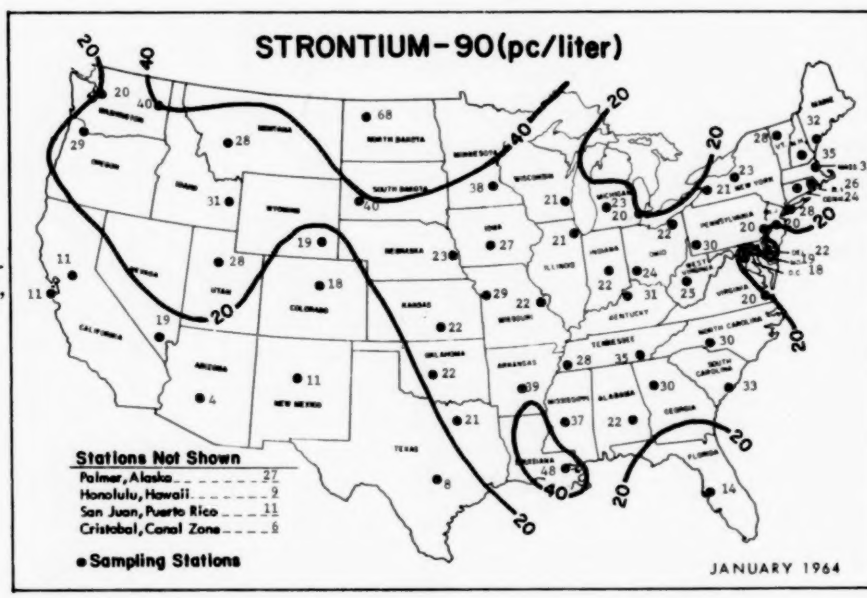

FIGURE 2.—STRONTIUM-90 CONCENTRATIONS IN PASTEURIZED MILK, JANUARY 1964

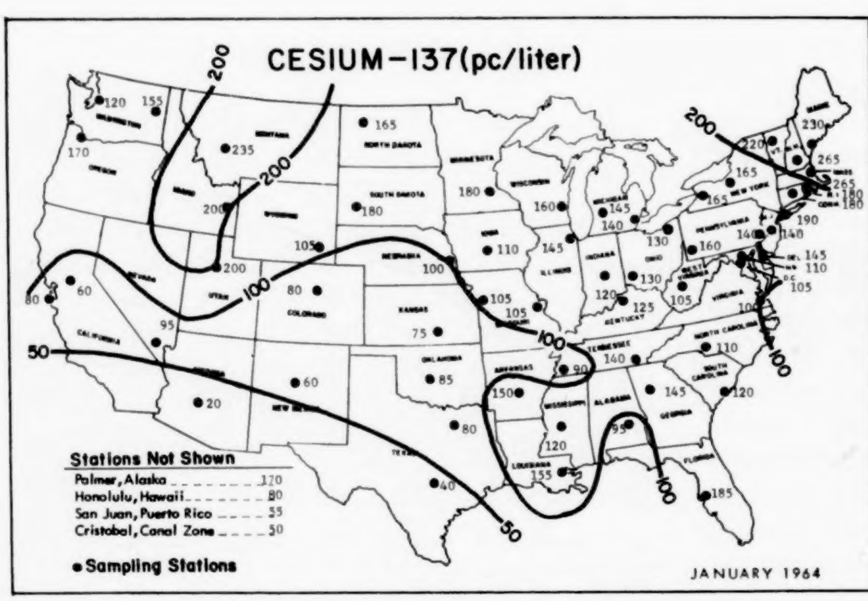

FIGURE 3.—CESIUM-137 CONCENTRATIONS IN PASTEURIZED MILK, JANUARY 1964

TABLE 3.—DISTRIBUTION OF SAMPLING STATIONS IN VARIOUS RANGES OF RADIONUCLIDE CONCENTRATIONS IN MILK, JANUARY 1964 [a]

Strontium-89		Strontium-90		Iodine-131		Cesium-137		Barium-140	
Range (pc/liter)	Number of stations	Range (pc/liter)	Number of stations	Range (pc/liter)	Number of stations	Range (pc/liter)	Number of stations	Range (pc/liter)	Number of stations
<5	43	<1–4	1	<10	63	<5–45	2	<10	63
5	6	5–9	3			50–95	13		
10	14	10–14	5			100–145	25		
		15–19	5			150–195	16		
		20–24	21			200–245	5		
		25–29	11			250–295	2		
		30–34	7						
		35–39	6						
		40–44	2						
		≥45	2						
Total	63	Total	63	Total	63	Total	63	Total	63

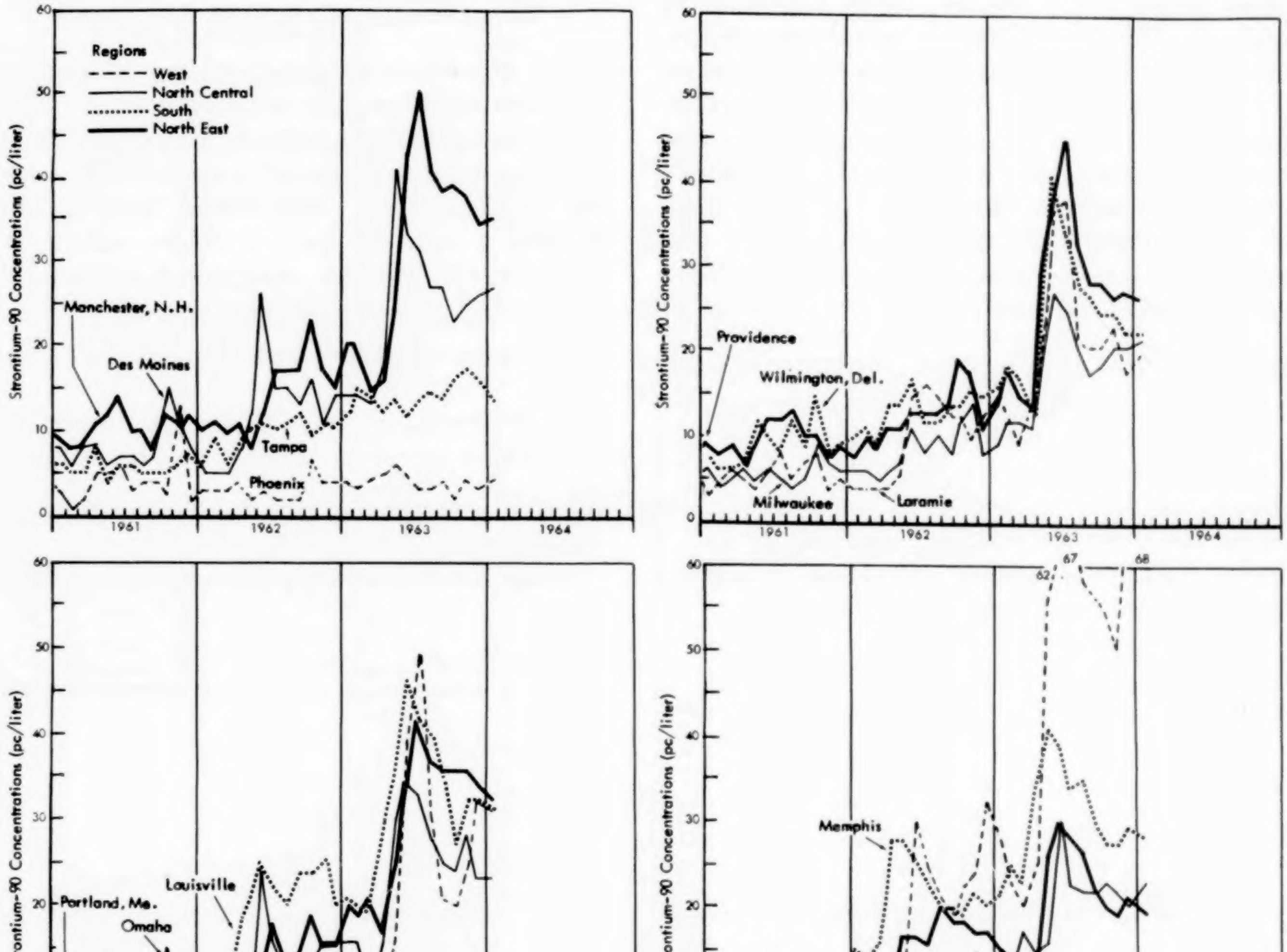

FIGURE 4.—STRONTIUM-90 CONCENTRATIONS IN PASTEURIZED MILK, FOR SELECTED CITIES, JANUARY 1964

2. Indiana Milk Network, January 1964

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radiological analysis in September 1961. Indiana was geographically divided into five major milksheds, and one large dairy within each milkshed was selected as a sampling station (see figure 5).

The milk samples are routinely analyzed for iodine-131, cesium-137, barium-140, strontium-89 and strontium-90. Until August 1963, analyses for the gamma emitters iodine-131, cesium-137 and barium-140 were conducted on a weekly basis, except when iodine-131 exceeded 100 pc/liter, at which times the frequency of sampling was increased. Because of continued low concentrations of the short-lived gamma emitters, the sampling frequency was reduced in August 1963 to once per month for the northeast, southeast and southwest milksheds. Strontium-89 and strontium-90 analyses are performed monthly for each station.

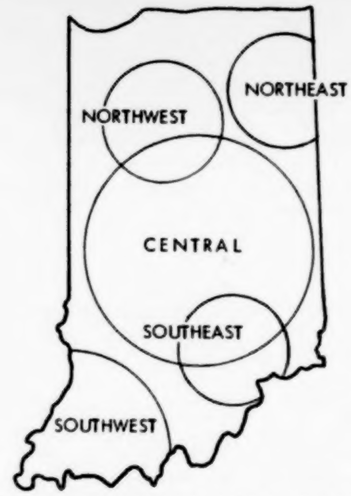

FIGURE 5.—INDIANA MILK SAMPLING LOCATIONS

An ion exchange analytical procedure (2) is used for strontium-89 and strontium-90 analyses. A 512-channel pulse height analyzer and shielded 4 x 4-inch sodium iodide crystal are used for the gamma analysis of iodine-131, cesium-137, and barium-140.

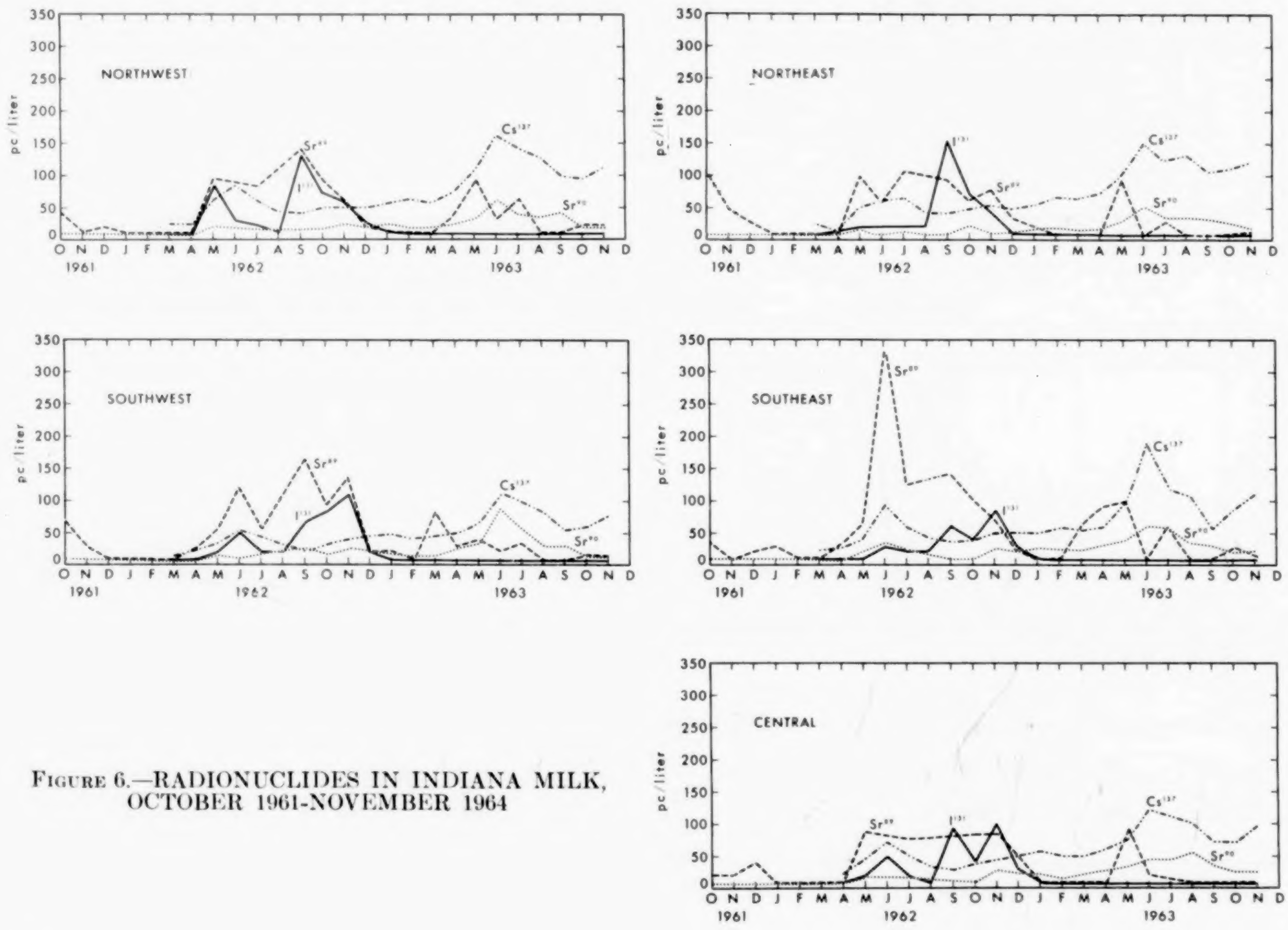

FIGURE 6.—RADIONUCLIDES IN INDIANA MILK, OCTOBER 1961-NOVEMBER 1964

The monthly averages of the data obtained for the individual sampling stations and the State averages are reported in table 4. The State average is an arithmetic average of the station values. Figure 6 summarizes the monthly averages of radionuclide concentrations at each station since beginning operation of the network.

TABLE 4.—RADIONUCLIDES IN INDIANA MILK, JANUARY 1964 [a]

[Concentrations in pc/liter]

Sampling location	Ca (g/liter)	K^{40}	Sr^{90}	Cs^{137}	Ba^{140}
Northeast	1.15	1280	27	125	0
Southeast	1.18	1260	21	115	10
Central	1.18	1290	25	115	0
Southwest	1.13	1290	29	125	0
Northwest	1.18	1290	25	130	0
State average	1.16	1280	25	120	0

[a] The monthly average iodine-131 and strontium-89 concentration at each station was zero.

3. Washington Milk Network,[1] December 1962—December 1963

Air Sanitation and Radiation Control Section State of Washington Department of Health

The Washington State Department of Health initiated a surveillance program for radioactivity in raw milk in December 1962. Ten collection points, shown in figure 7, were selected to provide samples representative of varying climatological conditions within the State's two major milksheds. As this sampling program also provides representation of a large percentage of the population's milk supply in the State, it would provide a basis for initiating countermeasures. Milk from Northwest Idaho (Sandpoint) is included in the network as this area forms a part of the Spokane milkshed. Several additional points are sampled from time to time.

Raw milk samples are collected routinely approximately every two weeks from individual tankers but the sampling frequency is flexible. Increased sampling can be initiated immediately if the need should arise.

Analytical Procedures

All milk samples are gamma scanned for 100 minutes in a 2-liter stainless steel Marinelli beaker. This beaker, which is placed on a 3″ x 3″ NaI (Tl) crystal, provides equal sample thickness on all sides and top of the crystal. The spectra are recorded with a 512-channel analyzer. A 4″ x 4″ matrix is used to analyze the spectra and provide rapid quantitative results for iodine–131, barium–140, cesium–137, and potassium–40.

An 800-minute background count is taken once each week. In order to check the stability of the analyzer, a one-minute count each day of a cesium–137 standard (solid) is done as an efficiency check, and a ten-minute count each week of the same source is done as a check on

[1] Data from *Environmental Radiation Surveillance in Washington State*, Second Annual Report, August 1963 and Monthly Surveillance Reports, *Radioactivity in Milk*.

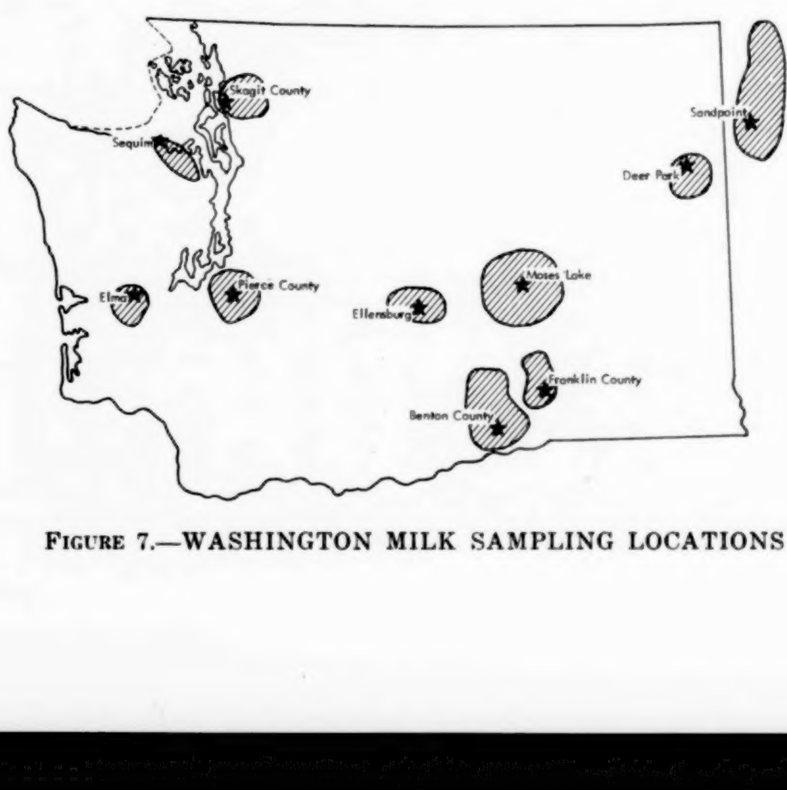

FIGURE 7.—WASHINGTON MILK SAMPLING LOCATIONS

resolution. These counts must fall within two standard deviations of the average for the analyzer to be considered to be working normally. Table 5 gives the gamma efficiencies and detectability limits for this system.

Table 5.—BETA AND GAMMA EFFICIENCIES AND LIMITS OF DETECTABILITY

	Energy band (Mev)	Efficiency (%)	Average background [a] (pc)	Limits of detectability (pc)
Gamma				
K^{40}	1.37–1.55	0.18	2277	325
I^{131}	0.33–0.40	4.20	300	20
Cs^{137}	0.62–0.72	2.60	246	30
Ba^{140}	0.46–0.57	3.50	326	30
Beta				
Y^{90}	—	70	8.0	1.7

[a] Counts per minute expressed as pc.

Following gamma scanning, selected samples are analyzed for strontium–90. After the addition of strontium carrier, the milk proteins are precipitated with trichloracetic acid. Oxalic acid is then added to the sample to precipitate the alkaline earths as oxalates (pH 3.0). The oxalates are ashed, dissolved in 6 *N* hydrochloric acid, and the pH is adjusted to 1.4 to dissolve the ash. A double extraction using an equal volume of 20 percent di-(2-ethylhexyl) phosphoric acid (HDEHP) in toluene is performed. This effectively removes rare-earth activity, including yttrium–90, leaving the strontium–90 in the sample. This sample is stored a minimum of two weeks to allow yttrium–90 to ingrow. Subsequently, the yttrium–90 is extracted with 5 percent HDEHP in toluene solution. The organic layer is scrubbed with an HCl solution (pH 1.4) and back extracted with 3N HNO_3. The resulting nitric acid solution is evaporated and yttrium–90 count from which the strontium–90 activity is calculated.

The yttrium–90 counting is done in a gas flow internal proportional counter. The efficiency and detectability limits are shown in table 5.

In addition to the solvent extraction method which is used for routine analysis of strontium–90, an ion exchange method has recently been used. Where available, the results from both methods have been averaged and are presented in table 6.

As a part of the laboratory's quality control program some samples are split and analyzed several times. Split samples are also exchanged with State, Federal and university laboratories for analyses and comparisons.

Table 6.—RADIONUCLIDE CONCENTRATIONS IN WASHINGTON MILK

[Concentrations in pc/liter]

	Potassium-40													Strontium-90						
	1962	1963												1962	1963					
	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Benton Co.			1252	1025	1282	1265	1200	967	1074	1156		1437				8			17	
Deer Park	1208	1328	1240	1048	1274	1173	1235	1243	1236	1211	1215	1193	1327	11	14		26		35	35
Ellensburg	1335	1164	1159	1196											8		8			
Elma	1280	1354	1226	1189	1188	1197	1232	1277	1290	1323	1250	1268	1282	9		10			32	
Franklin Co.			1240	1189	1173		1303	1193	1290		1338		1434			9				6
Moses Lake	1266	1195	1319	1233	1243	1159	1474	1230	1244	1217	1255	1227	1273		5		<2		14	5
Pierce Co.	1222	1253	1585	1273	1236	1269	1244	1285	1362	1208	1263	1297	1457		7		7			22
Sandpoint, Idaho	1188	1295	1151	1129		1249	1225	1284	1272	1257	1195	1399	1270	15	20		17		46	44
Sequim	1069	1254	1204	1197	1264	1293	1245	1238	1161	1176	1308	1279	1219		2		10		22	
Skagit Co.	1191	1192	1206	1146	1171	1222	1137	1281	1226	1240	1158	1312	1378		8		14			24

	Strontium-90-Contineed						Iodine-131 [a]	Cesium-137													Ba^{140}
	1963						1962	62	1963												62 [b]
	July	Aug.	Sep.	Oct.	Nov.	Dec.	Dec.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Dec.
Benton Co.	27	11	20		16					40	51	66	134	78	166	77	86		88		
Deer Park	28	42	26	31	35	29	<10	82	93	63	78	106	163	171	205	172	156	145	170	161	<15
Ellensburg							<10	68	67	72	67										<15
Elma	17		46	33	23	15	<10	58	49	46	49	60	103	194	155	174	186	178	112	72	<15
Franklin Co.		12								50	38	177		64	114	78		50		77	
Moses Lake	13	12	12	12	14		<10	68	36	46	46	67	75	44	126	79	83	79	88	89	<15
Pierce Co.	30		52	21		20	29	80	71	81	63	172	274	164	228	285	324	149	209	123	27
Sandpoint, Idaho	50	32	46	51	59	51	<10	103	112	105	107		202	248	451	308	298	276	305	318	<15
Sequim		21		31		22	<10	67	97	58	77	83	65	98	243	111	142	260	186	158	<15
Skagit Co.	15	39		22	24	22	20	84	75	71	69	83	128	139	166	216	170	231	195	199	<15

[a] All I^{131} monthly averages when samples were taken during 1963 were <10.

[b] All Ba^{140} monthly averages when samples were taken during 1963 were <15. Exception: In June 1963 the Sequim average was 16 and the Skagit average was 21.

Results

Table 6 presents the monthly average radionuclide content of raw milk for ten of the production areas in the major milksheds. Iodine-131 and barium-140 have in general been nondetectable in 1963. For both cesium-137 and strontium-90 the Sandpoint production area had somewhat higher concentrations than the other areas during the period reported. Benton, Franklin, and Moses Lake have usually had the lower monthly averages.

4. Canadian Milk Network,[2] January 1964

Radiation Protection Division
Department of National Health and Welfare, Ottawa, Canada

The Radiation Protection Division of the Department of National Health and Welfare began monitoring milk for strontium-90 in November 1955. At first, analyses were carried out on samples of powdered milk obtained from processing plants. However, since January 1963, liquid whole milk has been analyzed instead. With this change, more representative samples of milk consumed can be obtained, and in addition it is possible to choose milk sampling locations (see figure 8) in the same areas as the air and precipitation stations. At present, the analyses include determinations of iodine-131, strontium-89, cesium-137 and strontium-90 as well as stable potassium and calcium.

The milk samples are obtained through the cooperation of the Marketing Division of the Canadian Department of Agriculture. At each station, samples are collected three times a week from selected dairies, combined into weekly composites, and forwarded to the radiochemical laboratory in Ottawa. The contribution of each dairy to the composite sample is directly proportional to its volume of sales. In most cases a complete sample represents over 80 percent of the milk processed and distributed in the area. Several of the weekly samples are randomly selected and analyzed for iodine-131. The results of the spot checks for iodine-131 will not be reported unless there is evidence that the levels are rising. A monthly composite of the samples is analyzed for strontium-90, strontium-89, cesium-137, and stable potassium and calcium.

Analytical Methods

Radiochemical methods are used for the analysis of iodine-131 (*3*). Carrier iodine is added and the milk is then evaporated in the presence of sodium hydroxide and ashed. The iodine ion is oxidized to free iodine and extracted with carbon tetrachloride, back-extracted in sulfite solution, and precipitated as silver iodide. The precipitate is counted in a low background beta counter and the iodine-131 determined by comparison with standard preparations.

[2] Data from *Radiation Protection Programs, Vol. 2, No. 2*, Radiation Protection Division, Canadian Department of National Health and Welfare, Ottawa, Canada (February 1964).

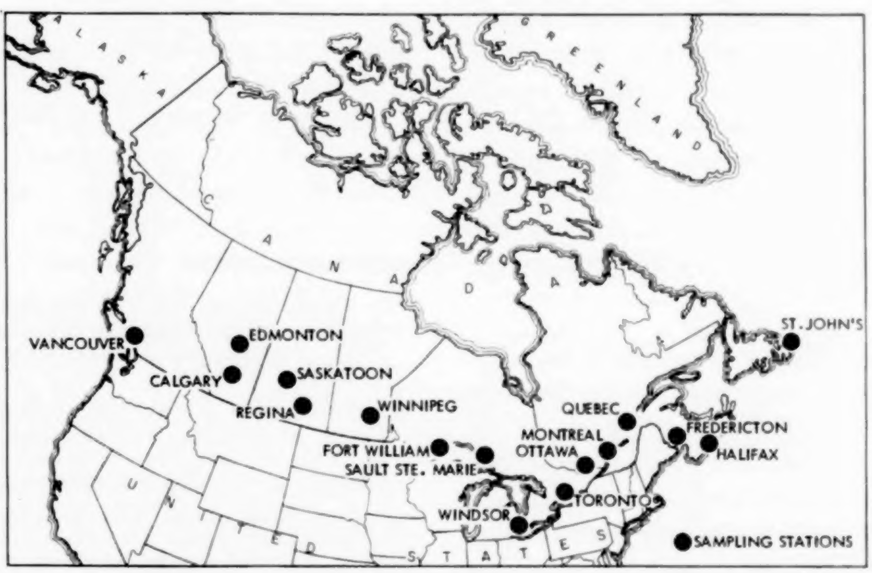

FIGURE 8.—CANADIAN MILK SAMPLING STATIONS

For the analysis of radiostrontium, carrier strontium is added to a one-liter sample of milk, and the milk is then placed in a tray lined with a polyethylene sheet, and evaporated under infra-red lamps. The residue is ashed in a muffle furnace at 450°C, dissolved in dilute nitric acid, and strontium separated by fuming nitric acid precipitation. The combined strontium–89 and strontium–90 are determined by counting in a low background beta counter. Strontium–90 is determined separately by extracting and counting the yttrium-90 daughter nuclide while strontium–89 is estimated by difference from the total radiostrontium measurement. Appropriate corrections are made for self-absorption and counter efficiency at all stages. Calcium is determined by flame photometry.

Cesium–137 is determined by gamma spectroscopy using a scintillation crystal and a multi-channel pulse height analyzer. A sample consisting of 4.5 liters of milk is placed in a sample tray constructed in the form of an inverted well to accommodate the 5 x 4-inch sodium iodide crystal detector. The sample is counted for 100 minutes and the gamma spectrum recorded. Estimates are made of the potassium–40 and cesium–137 content of the milk by comparison of the spectrum with standard preparations. The stable potassium content is estimated from the potassium–40 concentration.

Sources of Error

In the iodine and strontium determinations, tests indicate that the statistical error (95 percent confidence level) in the chemical operations involved is about plus-or-minus 10 percent. This value is independent of the concentration of the radioisotope in the milk because it depends only on the recovery of the carrier. In the determination of cesium-137 this factor is not involved.

The chemical procedures error must be combined with the counting error which depends primarily on the concentration of the nuclide in the sample, the background radiation, and the length of time the sample and background are counted. This counting error has been evaluated mathematically for the particular counting arrangement used.

The overall errors estimated on the basis indicated above, are given in table 7.

TABLE 7.—TOTAL ERROR FOR VARIOUS RADIONUCLIDE CONCENTRATIONS IN MILK [a]

Nuclide	Error for 10 pc/liter	Error for 50 pc/liter	Error for 100 pc/liter
Strontium-89	±25%	±20%	±15%
Strontium-90	±15%	±10%	±10%
Iodine-131	±50%	±20%	±10%
Cesium-137	±60%	±25%	±10%

[a] All errors are 2σ values, representing 95 percent confidence.

Results

Table 8 presents monthly averages of strontium–89, strontium–90, cesium–137, and stable calcium and potassium in Canadian whole milk. Spot checks for iodine–131 indicate that all samples had <5 pc/liter.

TABLE 8.—RADIONUCLIDES IN CANADIAN WHOLE MILK, JANUARY 1964

[Radionuclide concentrations in pc/liter]

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90	Cesium-137
Calgary	1.31	1.5	50.6	299
Edmonton	1.29	1.6	39.2	232
Ft. William	1.23	1.7	57.4	299
Fredericton	1.29	1.6	56.6	378
Halifax	1.30	1.7	41.2	279
Montreal	1.25	1.7	44.3	285
Ottawa	1.27	1.7	30.1	232
Quebec	1.21	1.6	56.0	239
Regina	1.24	1.6	54.7	216
St. John's, Nfld	1.21	1.5	38.6	262
Saskatoon	1.28	1.7	59.0	242
Sault Ste. Marie	1.26	1.6	42.0	224
Toronto	1.32	1.6	20.0	141
Vancouver	1.38	1.7	32.9	266
Windsor	1.27	1.6	19.9	118
Winnipeg	1.20	1.7	46.5	249
Average	1.27	1.6	43.1	254

REFERENCES

(*1*) Public Health Service: Summary of Results from the Raw Milk Sampling Program, June 1957-April 1963, *Radiological Health Data, 4*:511-23 (October 1963).

(*2*) Porter, C., D. Cahill, R. Schneider, P. Robbins, W. Perry, and B. Kahn: Determination of Strontium-90 in Milk by an Ion Exchange Method, *Analytical Chemistry, 33*:1306-8 (September 1961).

(*3*) DasGupta, A. K., and H. G. Green: *A Method for the Radiochemical Determination of Iodine-131 in Milk, RPD-23*, Radiation Protection Division, Department of National Health and Welfare, Ottawa, Canada (October 1963).

MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK, FEBRUARY 1963–JANUARY 1964

Division of Radiological Health, Public Health Service

Radionuclide concentration values reported by the Pasteurized Milk Network (*1*) can be used to assess the contribution of milk to an individual's or a population's radiation exposure. This is done by determining both the annual average concentrations of specific radionuclides in milk and the average daily milk consumption of an individual or a suitable sample of the population.

The data listed in table 1 are concerned with the first of these requirements, *i.e.*, annual average concentrations of strontium–89, strontium–90, iodine–131 and cesium–137 in one liter of pasteurized milk. Limited data are available for estimating the average daily milk consumption (on a volume basis) for specific age groups in the U. S. population (*2, 3*).

To arrive at a basis of comparison between the daily rates of intake of the radionuclides from the milk component of the diet and the Federal Radiation Council's ranges of transient daily rates of intake (*4*), it is assumed that the average daily milk consumption of an individual in a population group is one liter. The Guides, however, apply to total intake from all foods. The upper limits of intake Range II correspond to the Radiation Protection Guide (RPG) for iodine–131 and one-third of the Radiation Protection Guide for radioactive strontium. The Guides are, for administrative reasons, expressed as a yearly radiation dose, but are based on lifetime exposure (*5*). However, the FRC emphasizes that the annual acceptable risk or exposure dose is not a dividing line between safety and danger in actual radiation situations (*6*). The ICRP has set the maximum permissible concentration (MPC) for cesium–137 in water for the population at large equal to 2000 pc/liter (*7*). This MPC may be applied to milk if it is assumed that all food would be contaminated to the same extent.

Annual averages of radionuclide concentrations in milk sampled by the PHS Pasteurized Milk Network are presented in table 1. The data in table 1 are calculated as follows: (a) results from all samples collected in each week (Sunday through Saturday) are averaged, (b) the averages for all weeks ending in twelve consecutive months are averaged to obtain the annual average.[1] To obtain the annual average daily intake (pc/day) of radionuclides from milk, the annual average concentration values (pc/liter) in table 1 must be multiplied by the annual average daily consumption (liters/day) of milk (*3, 4*).

Monthly variations of radionuclide concentrations in milk are due to a number of combined causes. The moving yearly average (table 1), obtained by updating the previous twelve-month average by one month, shows variations averaged over the year and tends to minimize purely seasonal variations. This method, therefore, shows trends over a considerable period of time.

REFERENCES

(*1*) Public Health Service: Milk Surveillance—Pasteurized Milk Network, *Radiological Health Data*, *5*:57 (February 1964).

(*2*) Bureau of the Census, and Public Health Service: National Food Consumption Survey, Fresh Whole Milk Consumption in the United States, July 1962, *Radiological Health Data* *4*:15-17 (January 1963).

(*3*) Bureau of the Census and Public Health Service: Consumption of Selected Food Items in U. S. Households, July 1962, *Radiological Health Data*, *4*:124-7 (March 1963).

(*4*) Federal Radiation Council: Radiation Protection Guidance for Federal Agencies, *Federal Register*, Superintendent of Documents, Government Printing Office, Washington, D. C. 20402 (September 26, 1961).

(*5*) Federal Radiation Council: *Background Material for the Development of Radiation Protection Standards, Report No. 2*, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402 (September 1961), price 20 cents.

(*6*) Public Health Service: Special Report, *Radiological Health Data*, *3*:ii-iii (September 1962).

(*7*) International Commission on Radiological Protection: *Report of Committee II on Permissible Dose for Internal Radiation*, Pergamon Press, New York (1959).

[1] Beginning with the October 1963 data, iodine-131 values of <10 pc/liter are considered to be zero for averaging purposes; previously 5 pc/liter was used in calculating the average.

Table 1.—MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN MILK[a]

[Concentrations in pc/liter]

Sampling locations		Strontium-89		Strontium-90		Iodine-131		Cesium-137	
		January 1963 December 1963	February 1963 January 1964	January 1963 December 1963	February 1963 January 1964	January 1963 December 1963	February 1963 January 1964	January 1963 December 1963	February 1963 January 1964
Ala:	Montgomery	59	53	21	21	4	3	76	80
Alaska:	Palmer	30	29	21	22	5	3	117	123
Ariz:	Phoenix	12	11	4	4	4	3	22	22
Ark:	Little Rock	111	101	42	43	8	5	148	154
Calif:	Sacramento	38	37	10	10	6	3	58	61
	San Francisco	71	67	13	14	5	3	70	74
Colo:	Denver	26	25	16	17	6	5	83	84
Conn:	Hartford	21	21	23	24	4	3	143	152
Del:	Wilmington	28	27	25	25	4	4	121	127
D. C:	Washington	38	37	19	20	4	3	92	96
Fla:	Tampa	30	28	14	14	6	5	215	221
Ga:	Atlanta	83	76	29	30	5	4	137	142
Hawaii:	Honolulu	34	31	10	11	6	5	73	75
Idaho:	Idaho Falls	43	49	23	24	5	3	131	140
Ill:	Chicago	18	18	20	21	4	3	101	107
Ind:	Indianapolis	28	28	23	23	4	3	93	97
Iowa:	Des Moines	57	56	24	25	5	3	87	91
Kans:	Wichita	41	39	19	19	5	3	70	72
Ky:	Louisville	84	82	32	32	4	3	102	108
La:	New Orleans	135	123	42	43	8	7	147	154
Maine:	Portland	26	26	30	31	4	3	191	200
Md:	Baltimore	46	46	21	21	4	3	116	119
Mass:	Boston	31	31	33	34	4	3	206	219
Mich:	Detroit	16	16	20	20	4	3	105	110
	Grand Rapids	18	17	20	20	5	4	110	115
Minn:	Minneapolis	48	47	29	30	5	3	142	148
Miss:	Jackson	127	115	35	36	7	5	108	113
Mo:	Kansas City	65	63	26	27	4	3	78	83
	St. Louis	47	46	21	22	5	3	82	85
Mont:	Helena	46	45	26	27	5	4	160	171
Nebr:	Omaha	49	47	24	25	5	3	92	95
Nev:	Las Vegas	17	17	8	9	4	4	65	69
N. H:	Manchester	29	29	32	33	5	5	230	242
N. J:	Trenton	21	21	21	21	4	3	113	119
N. Mex:	Albuquerque	21	19	9	10	4	3	41	43
N. Y:	Buffalo	21	21	22	23	4	3	128	133
	New York	29	29	28	29	4	3	147	156
	Syracuse	24	24	23	23	4	4	122	130
N. C:	Charlotte	65	63	31	31	4	3	114	119
N. Dak:	Minot	82	81	47	50	5	4	130	136
Ohio:	Cincinnati	35	34	25	26	5	4	84	89
	Cleveland	23	23	21	21	4	3	100	105
Okla:	Oklahoma City	62	58	23	23	6	4	85	87
Ore:	Portland	71	67	28	29	4	3	150	157
Pa:	Philadelphia	26	25	23	24	4	3	115	120
	Pittsburgh	33	33	28	29	4	4	137	144
P. R:	San Juan	69	57	14	14	8	6	88	88
R. I:	Providence	26	25	26	27	4	4	151	159
S. C:	Charleston	63	59	26	27	6	5	118	123
S. Dak:	Rapid City	65	64	35	37	5	4	139	147
Tenn:	Chattanooga	100	95	36	37	4	3	133	140
	Memphis	87	80	31	31	5	3	84	88
Tex:	Austin	30	25	9	9	6	3	44	45
	Dallas	68	58	21	21	7	5	78	80
Utah:	Salt Lake City	33	32	22	23	6	5	145	153
Vt:	Burlington	25	25	27	28	4	3	161	171
Va:	Norfolk	45	43	22	22	4	3	97	100
Wash:	Seattle	56	53	24	25	5	3	145	149
	Spokane	49	49	25	27	5	4	132	137
W. Va:	Charleston	65	64	29	29	4	4	93	98
Wis:	Milwaukee	18	18	18	19	4	4	106	113
Wyo:	Laramie	38	37	21	21	4	3	115	115
Network average		47	45	23.7	24.4	5	4	114	119

[a] Annual averages were computed on the basis of 52 weekly averages.

STRONTIUM-90 IN 1963 HARVEST OF SELECTED GRAINS—PRELIMINARY REPORT

Division of Pharmacology, Food and Drug Administration

Because of the finding in 1963 of elevated levels of strontium-90 in wheat harvested mainly in Kansas, it was decided to study the impact of 1963 fallout on wheat and other grains in more detail. Table 1 lists preliminary analytical results for barley, oats, rye, and wheat by States where data are available for both 1962 and 1963.

Even though this is a preliminary survey with all analytical results on the 1963 harvest not yet available, it is clear that there have been substantial increases in the strontium-90 concentrations in these four grains. Also, with few exceptions, individual 1963 results range higher than their 1962 counterparts.

TABLE 1.—PRELIMINARY 1963 STRONTIUM-90 RESULTS FOR SELECTED GRAINS COMPARED WITH 1962 RESULTS

State	Barley				Oats				Rye				Wheat					
	1962		1963		1962		1963		1962		1963		1962			1963		
	No. of samples	Sr^{90} (pc/kg)	No. of samples	Sr^{90} (pc/kg)	No. of samples	Sr^{90} (pc/kg)	No. of samples	Sr^{90} (pc/kg)	No. of samples	Sr^{90} (pc/kg)	No. of samples	Sr^{90} (pc/kg)	No. of samples	Sr^{90} (pc/kg) average	Sr^{90} (pc/kg) range	No. of samples	Sr^{90} (pc/kg) average	Sr^{90} (pc/kg) range
Ala.	1	104	2	325														
Calif.	a				4	12	1	10										
Colo.	2	19	2	79					1	30	1	55	4	66	11–135	1	365	—
Ga.					2	131	1	44										
Idaho	1	2.9	1	65	1	15	1	184					5	16	4.6–34	1	53	
Ill.													9	80	9.0–158	1	114	
Ind.					1	82	1	309					4	74	53–90	9	180	50–453
Kans.					3	65	1	193					9	46	6.8–92	18	779	73–1340
Ky.	2	88	1	359														
Md.					1	48	1	127	1	9	2	47						
Mich.					1	97	1	216					3	81	36–159	6	230	20–509
Miss.													5	144	76–241	5	127	108–143
Mo.	1	73	2	389					1	124	2	242	3	32	16–40	2	202	189–215
Nebr.									1	179	1	518	4	144	48–271	2	249	19–478
N. J.													1	16		1	158	
N. C.													2	99	72–126	1	120	
N. D.	2	81	2	49														
Ohio					1	84	1	127	1	58	3	224	5	63	47–103	14	116	4.0–242
Ore.	1	22	1	62	2	13	1	92					1	16		1	64	
Pa.	2	68	1	626					1	31	1	69	4	41	35–48	1	160	
S. C.					1	187	2	393	1	168	2	147	3	119	106–134	3	167	17–289
Tex.													8	94	15–182	3	341	209–604
Utah									1	28	1	95	2	28	27–28	2	25	6.8–44
Va.													2	77	67–87	4	103	24–136
W. Va.					1	90	1	132										
Wyo.													3	49	8.9–97	1	192	

[a] Blank indicates no data available.

STRONTIUM-90 IN FOODS AT INTERMEDIATE STAGES OF PREPARATION FOR CANNING AND FREEZING

Division of Pharmacology, Food and Drug Administration

For the past few years, the Food and Drug Administration (FDA) has conducted an extensive surveillance program on radioactivity in domestic and imported foods (*1*). This program has been largely directed at assessing the degree of radioactive contamination (including strontium-90) in individual foods, and the total diet. In addition, considerable attention has also been focused on commercial processing of foods in an attempt to learn what effects such operations have on removing radioactive contamination. Presented below are the results of FDA studies on the effect of individual processing steps on the strontium-90 content of foods. These studies were done in collaboration with the National Canners Association and the Association of Frozen Food Packers.

Canned Fruits and Vegetables

Studies were conducted on peaches, tomatoes, and snap beans to determine what effect typical food preparative procedures, conducted prior to canning would have on the strontium-90 content of these foods. The preparative procedures consisted of (1) chemical removal of peach skins, (2) mechanical removal of tomato skins and cores, and (3) washing and blanching of snap beans. The products were harvested in August 1962 and processed in an experimental pilot plant of the National Canners Association at Berkeley, California. The determination of strontium-90 and stable strontium on the various processed segments was done in the FDA laboratories in Washington, D. C. Strontium-90 was analyzed following the method of Harley (*2*) and stable strontium was analyzed by a standard X-ray fluorescence method (*3*).

Peaches

The distribution of strontium-90 in raw peaches was studied both before and after peeling. Peeling of the halved and pitted fruit was done with hot (218°F) two percent lye solution. Fresh water spray rinsing followed the peeling step.

Results: The removal of peach skins resulted in a significant reduction of strontium-90 in the peach, as shown in table 1. Since the peeling losses were recorded for each lot, the strontium-90 content of the peel could be calculated. The results showed that a comparatively sizable burden of strontium-90 must occur in this portion of the fruit. A pooled sample of peach pits was also analyzed; this portion of the fruit had a concentration of 1.1 pc/kg, about the same as the flesh.

Because of the limited number of stable strontium analyses and their variability, little information can be deduced from these data. However, it may be observed that the concentration of stable strontium tends to be higher in the peeled peach than in the whole peach.

TABLE 1.—EFFECT OF PEELING ON THE STABLE STRONTIUM AND STRONTIUM-90 CONTENT OF PITTED PEACHES

Type	Sample number	Unpeeled		Peeled		Difference	Skins	
		Sr^{90} (pc/kg)	Stable strontium (μg/kg)	Sr^{90} (pc/kg)	Stable strontium (μg/kg)	Sr^{90} content (pc/kg)	Portion of whole fruit (percent)	Calculated Sr^{90} (pc/kg)
Cling	85-479	1.5	34		47		7.6	
	85-475	2.5		1.9		0.6	8.2	7.3
	85-477	3.4	83	2.1	123	1.3	11	12
	85-473	2.5		0.8		1.7	9.9	17
	85-481	2.7		1.1		1.6	6.1	26
	85-483	3.9	92	0.8		3.1	6.2	50
	85-493	3.7		1.4		2.3	5.1	45
	85-491	1.1		0.6		0.5	5.5	9
	85-489	1.9	112	0.1	191	1.8	5.9	31
Freestone	85-485	2.5	132		136		4.2	
	85-487	2.5	60	1.7	37	0.8	6.7	12
Average Sr^{90} content (pc/kg)		[a] 2.6		[a] 1.2				
Average stable strontium content (μg/kg)			85		107			

[a] Significance: 2.6 *vs.* 1.2 p=0.001

Snap Beans

Strontium–90 was similarly investigated in raw and unwashed, washed and blanched, and in heat-processed beans. Washing was done in warm (80°F) 0.05 percent detergent solution, followed by a fresh water rinse. This was followed by an 8 to 10 minute blanching in water at 205°F. Finally, the blanched beans were heat-processed at 250°F for 15 minutes.

Results: The strontium–90 content of snap beans following these three preparative procedures given in table 2 shows that the combined washing and blanching process removed strontium–90 from the raw bean (1.8 pc/kg *vs.* 0.89 pc/kg, $p = 0.15$). While the difference was not statistically significant at the 95 percent level of confidence, nevertheless, a trend is suggested. Inspection of the data also showed that there was no difference between washed and blanched and heat-processed beans. Stable strontium data disclosed no significant difference between the three treatments. Variations noted are ascribed to random analytical errors inherent in the method. Assuming that the stable strontium which occurs within the tissues of the plant is not labile, such a finding could be expected, since only the surface strontium would be removed. Furthermore, the reduction of the Sr^{90} to stable strontium ratio in beans between the steps from raw to washed and blanched was interpreted to be due to removal of strontium–90 from the surface and not from internal structures.

Tomatoes

The experimental processing of tomatoes to study the distribution of strontium–90 was done on whole, unwashed, unpeeled tomatoes; whole, washed, unpeeled tomatoes; peeled and cored tomatoes; and waste residue, comprising peels and cores.

Washing was done with warm (80°F) 0.05 percent commercial detergent solution to which was added 8 percent sodium dodecylbenzenesulfonate. The detergent solution was recirculated through five pairs of narrow-angle, flat-jet nozzles at 10 psi, equivalent to a total of 10 gallons per minute of recirculated solution. Following the wash, the tomatoes were rinsed twice. The first rinse was at 80°F, and the second at 60°F. Peeling and coring was done by hand after the fruit had been immersed for three minutes in 205°F water.

Results: The strontium–90 content of the five segments is given in table 3. The strontium–90 concentration in tomatoes is low and presents certain analytical difficulties. The results, however, were interpreted as follows: there was no difference in strontium–90 content of washed and unwashed tomatoes, and peeling and coring removed strontium–90 (0.64 pc/kg *vs.* 0.39 pc/kg, $p = 0.25$). Although the difference was not significant at the 5 percent level, a trend was nevertheless indicated. Coring accounted for the removal of strontium–90

TABLE 2.—EFFECT OF PROCESSING ON THE STRONTIUM-90 CONTENT OF SNAP BEANS

Sample number	Raw Beans			Washed and Blanched			Heat Processed		
	Sr^{90} (pc/kg)	Stable strontium (μg/kg)	Sr^{90}/stable strontium (pc/μg)	Sr^{90} (pc/kg)	Stable strontium (μg/kg)	Sr^{90}/stable strontium (pc/μg)	Sr^{90} (pc/kg)	Stable strontium (μg/kg)	Sr^{90}/stable strontium (pc/μg)
85–421	0.10	194	0.052x10	0.67			0.77	165	0.47×10^{-2}
85–422	3.6	196	1.8 x10	0.39	174	0.22×10^{-2}	0.89	168	0.53×10^{-2}
85–424	0.14	205	0.068x10	0.17	209	0.08×10^{-2}	0.21	175	0.12×10^{-2}
85–425	4.5	189	2.38 x10	2.8	219	1.28×10^{-2}	2.2	263	0.84×10^{-2}
85–427	1.7			0.88	116	0.76×10^{-2}	0.58	159	0.36×10^{-2}
85–428	0.21	104	0.20 x10	0.0	118		0.09		
85–430	2.1	134	1.57 x10	0.73	145	0.50×10^{-2}	1.0	125	0.80×10^{-2}
85–431		104			133			148	
85–433	3.3			3.2	219	1.46×10^{-2}	2.1	270	0.78×10^{-2}
85–434	2.8	203	1.38 x10	0.09	223	0.04×10^{-2}	0.22	206	0.11×10^{-2}
85–435	0.84			0.57			0.50	256	0.20×10^{-2}
84–436	1.1	309	0.36 x10	0.39	297	0.13×10^{-2}	0.40	314	0.13×10^{-2}
Average Sr^{90} content (pc/kg)	[a] 1.8			[a] 0.89			0.82		
Average stable strontium content (μg/kg)		182	0.99 x10		205	0.43×10^{-2}		204	0.40×10^{-2}

[a] Significance: 1.8 *vs.* 0.89 $p = 0.15$

TABLE 3.—EFFECT OF PROCESSING ON THE STRONTIUM-90 CONTENT OF TOMATOES

Sample number	Whole	Washed Whole		Peeled and Cored		Peels		Cores
	Sr^{90} (pc/kg)	Sr^{90} (pc/kg)	Stable strontium (μg/kg)	Sr^{90} (pc/kg)	Stable strontium (μg/kg)	Sr^{90} (pc/kg)	Stable strontium (μg/kg)	Sr^{90} (pc/kg)
84-798	0.32	0.43		0.37		0.07		0.78
85-411	0.37	0.19		0.52				0.59
85-405	0.77	0.81		1.0		0.07		1.7
85-409	1.4	0.38		0.34				0.49
85-407	0.10	0.07		0.04		1.4		1.6
85-403	0.12	3.0	85	0.41	92	0.08		0.43
85-401	0.50	0.57		0.34	91	0.10	78	0.83
85-419	0.60		24	0.29		0.96	0	0.90
85-417	0.49	0.49		0.20	120	0.23	89	0.43
85-415	0.55	0.39		0.48	38	1.4		2.2
85-413	0.51	0.63			140	1.0		1.3
84-796	1.0	0.15		0.35		0.87		
Average Sr^{90} concentration (pc/kg)	0.56	[a] [b] 0.64		[a] 0.39		0.62		[b] 1.02
Average stable strontium concentration (μg/kg)			55		96		84	

[a] Significance 0.64 *vs.* 0.39, p=0.25
[b] Significance 0.64 *vs.* 1.02, p=0.25

(0.64 pc/kg *vs.* 1.02 pc/kg, p = 0.25). Again this was interpreted as indicating a trend. Strontium-90 contamination seemed to be accounted for only by the core and not by the peel. The data did not warrant a deduction as to whether the strontium-90 content of the core resided internally or at the surface of the blossom and stem ends of the fruit. Because of the analytical limitations of the X-ray fluorescence method for determining stable strontium at the low levels found in tomatoes, too few analyses are reported to permit evaluation.

Frozen Vegetables

Experiments were conducted in the fall of 1962 to determine the effects of commercial freezing operations on the distribution of strontium-90 in plant parts. Broccoli and spinach were selected because their surface textures offered good opportunities for entrapment and retention of atmospheric fallout. With respect to distribution of fallout, it is of interest to note that more strontium-90 was found on broccoli leaves than on the flower portion—contrary to what might have been expected on the basis of surface area as a criterion.

Broccoli

Broccoli was harvested in Maryland on September 26, 1962 from three areas of a planting consisting of 118 rows. Four types of raw unprocessed samples were taken: five-inch heads with some preliminary trimmings, six-inch heads with large coarse leaves removed, side shoots, and leaf trimmings. Two types of frozen broccoli, pooled from the raw samples and processed at a local packer, were broccoli spears and chopped broccoli which consisted mostly of leaf trimmings and portions of heads and spears. The results of the analyses for strontium-90 are given in table 4.

TABLE 4.—DISTRIBUTION OF STRONTIUM-90 ON BROCCOLI

Sample	Sampling area (kg)	Strontium-90 content (pc/kg)
5-inch head	*Harvest Area Number 1*	40
6-inch head		38
Leaves		215
5-inch head	*Harvest Area Number 2*	42
Side shoots		15
Leaves		120
5-inch head	*Harvest Area Number 3*	52
6-inch head		29
Side shoots		14
Leaves		136
Chopped, frozen	*Processed Broccoli pooled from all areas*	28
Spears		2.7

Essentially there were no significant differences in strontium-90 concentrations between the five-inch and six-inch heads taken from three areas. Two samples of side shoots contained substantially less strontium-90—a finding that might be explained by the fact that the side shoots are perhaps not as fully exposed to

fallout as the heads. In contrast, leaves showed by far the highest strontium–90 concentration in any of the raw samples analyzed. Processing, such as washing and blanching preliminary to freezing, removed a considerable amount of surface strontium–90. This is shown clearly in the chopped samples, which are made up largely of leafy parts, and the spears. The difference between these processed samples was most readily explained by noting the differences observed in the raw product.

A substantial difference was observed in the distribution of strontium–90 between at least three edible portions of the broccoli plant; these differences were carried over to the frozen product. Each product (spears and chopped) lost over 80 percent of its original strontium–90 content during processing.

Consideration of climate caused variations in the distribution of strontium–90 in broccoli parts are beyond the scope of these studies.

Spinach

The spinach was harvested from six areas at a farm in New Jersey and was processed at a food packing plant. Four points on the processing production line were sampled, representing: unwashed spinach, washed spinach, blanched spinach, and cooled spinach. The last-named was equivalent to the frozen, commercially-packaged product.

Analyses were made for strontium–90 and for stable strontium. Results are given in table 5. With respect to strontium–90, the experiments indicated that the largest removal of this isotope occurred in the blanching process and not in the washing processes. This was interpreted to mean that a substantial part of the surface contamination of spinach is protected from removal by successive layers of wax cover left undisturbed by cold water washing. When these wax layers were stripped by blanching, the strontium–90 so uncovered was free to be removed by the hot water. As expected, no significant change in the strontium–90 level occurred when the blanched spinach was cooled prior to packaging and freezing.

With respect to stable strontium, the findings were interpreted as being indicative of *no* changes in its distribution during processing. Variations noted must be ascribed to random analytical errors inherent in the method.

Specific activities have been calculated for each treatment, i.e. pc Sr^{90}/μg stable strontium. The decrease in the ratio through the washing and blanching steps of the treatment showed

TABLE 5.—EFFECT OF PROCESSING ON STABLE STRONTIUM AND STRONTIUM-90 CONTENT OF SPINACH

Lot No. and (harvest date)	Unwashed			Washed			Blanched			Cooled		
	Sr^{90} (pc/kg)	Stable strontium (μg/kg)	Sr^{90}/stable strontium (pc/μg)	Sr^{90} (pc/kg)	Stable strontium (μg/kg)	Sr^{90}/stable strontium (pc/μg)	Sr^{90} (pc/kg)	Stable strontium (μg/kg)	Sr^{90}/stable strontium (pc/μg)	Sr^{90} (pc/kg)	Stable strontium (μg/kg)	Sr^{90}/stable strontium (pc/μg)
3-517 (10-11-62)	58	164	0.35	38	117	0.33	29	116	0.25	33	146	0.23
2-521 (10-11-62)	117	133	0.87	108	107	1.0	67	111	0.60	68	136	0.50
3-511 (10-16-62)	92	192	0.48	83	236	0.35	57	206	0.28	63	252	0.25
1-527 (10-16-62)	70	193	0.36	70	266	0.26	58	170	0.34	70	209	0.34
1-501 (10-25-62)	66	172	0.38	59	288	0.21	38	246	0.15	31	225	0.14
1-509 (10-26-62)	86	90	0.95	79	107	0.74	57	129	0.44	62	129	0.48
Average Sr^{90} concentration (pc/kg)	81			[a] 73			[a] 51			54		
Average stable strontium concentration (μg/kg)		157			187			163			182	
Average Sr^{90}/stable strontium ratio			0.57			0.48			0.34			0.32

[a] Significance: 73 vs 51, p=0.02

removal of strontium–90, which must have been from the surface and not from internal structures. Otherwise a systematic decrease of stable strontium levels would also have been noted. Stable strontium occurs only in the internal parts of the spinach plant by translocation from the soil, while strontium–90 results from direct deposition of fallout as well as translocation from the soil.

REFERENCES

(*1*) Food and Drug Administration: Survey of Radioactivity in Food, *Radiological Health Data*, *3*:476-81 (December 1962).

(*2*) U. S. Atomic Energy Commission, New York Operations Office: *Health and Safety Laboratory Manual of Standard Procedures, NYO-4700:* Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. (February 1960) price $1.75.

(*3*) Liebhafsky, H. A., H. G. Pfeiffer, E. H. Winslow, and P. D. Zemany: *X-Ray Absorption and Emission in Analytical Chemistry*, John Wiley and Sons, Inc., New York (1960).

Correction for April 1964 Issue

A portion of the first paragraph in the "PROCEDURES" section, page 181, April *RHD* article, "Radionuclides in Diets for Teenagers, May 1962—November 1963," was omitted in error. The correct version reads as follows:

To duplicate the diet of a 19-year old male, a list of 82 different items of food and drink was prepared. Quarterly samples of these items, covering a two-week consumption period, were purchased from national food chain stores. Efforts were made to locate the sources of the food items and to choose the samples for the broadest possible geographical representation.

Section III—Water

RADIOACTIVITY IN SURFACE WATERS OF THE UNITED STATES, NOVEMBER 1963

Division of Water Supply and Pollution Control, Public Health Service

Levels of radioactivity in surface waters of the United States have been under surveillance by the Public Health Service Water Pollution Surveillance System (formerly National Water Quality Network) since its initiation in 1957. Beginning with the establishment of 50 sampling points, this System has expanded to 128 stations as of April 1, 1964. These are operated jointly with other Federal, State, and local agencies, and industry. Samples are taken from surface waters of all major U. S. river basins for physical, chemical, biological and radiological analyses. These data can be used for evaluating sources of radioactivity which may affect specific domestic, commercial, and recreational uses of surface water. Further, the System provides background information necessary for recognizing pollution and water quality trends and for determining levels of radioactivity to which the population may be subjected. Data assembled through the System are published in an annual compilation (*1–6*).

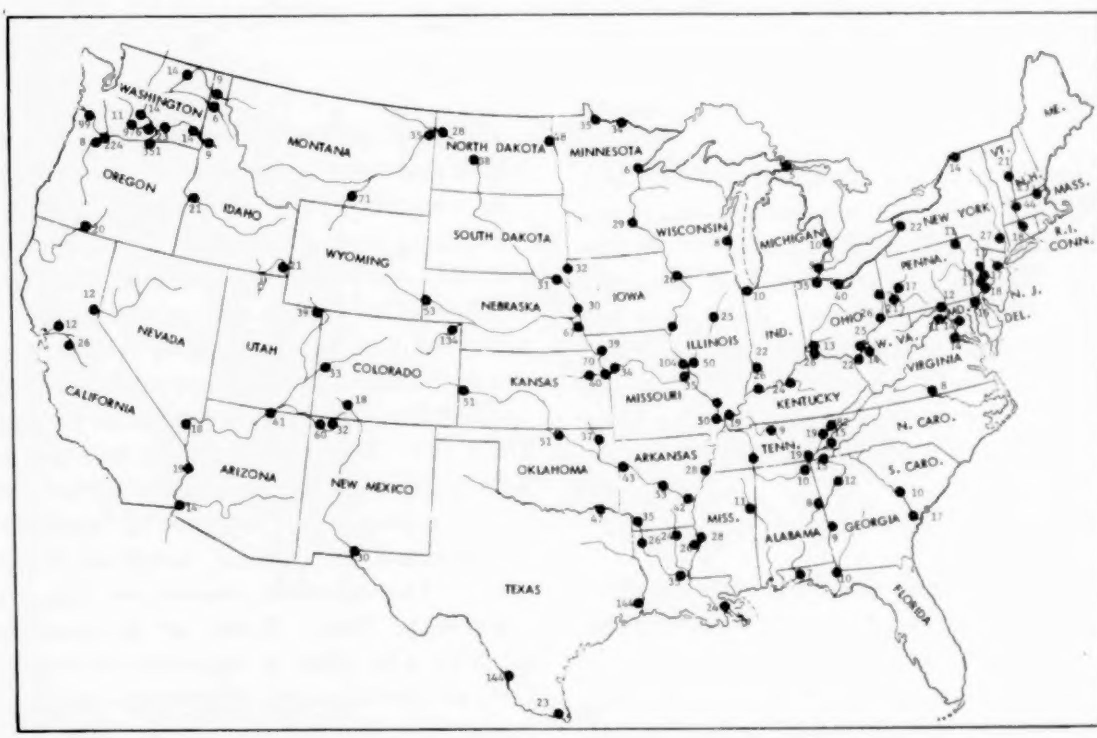

FIGURE 1.—TOTAL BETA ACTIVITY (pc/liter) IN SURFACE WATERS, NOVEMBER 1963

Sampling Procedures

The participating agencies collect one-liter "grab" samples each week and ship them to the PHS Robert A. Taft Sanitary Engineering Center in Cincinnati for analysis. Determinations of gross alpha and gross beta radioactivity in the suspended and dissolved solids and of strontium–90 activity in the total solids are carried out on frequency schedules based on need.

Gross beta activity in each weekly sample was determined until January 1960, when the levels became essentially equal to background. Thereafter, gross beta determinations were made on monthly composites of the weekly samples received from all stations, except those located downstream from known potential sources of radioactive waste and those from all newly established System stations. Weekly alpha and beta measurements are scheduled routinely during the first year of operation at newly established stations. On September 1, 1961, weekly determinations of gross beta activity again were instituted to permit early detection of activity due to fallout from renewed weapons testing. This practice was continued until the end of October 1962, when samples for gross beta analysis were again composited monthly. Gross alpha determinations were made once a month except where variable or high values observed during the first year indicated the need for more frequent measurement.

Normally, samples are counted within two weeks following collection or within one week after compositing. The decay of activity is followed on each sample when the first analysis shows unusually high activity. Also, if a recount indicates that the original analysis was questionable, values based on recounting are recorded. All results are reported for the time of counting and are not extrapolated to the time of collection.

Analytical Methods

The analytical method used for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*7*). Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 microns. Planchets are then prepared for counting the dissolved solids (in the filtrate) and the suspended solids (on the charred membrane filter) in an internal proportional counter. Reference sources of U_3O_8, which give a known count rate if the instrument is in proper calibration, are used for daily checking of the counters.

Since the fourth quarter of 1958, strontium–90 analyses have been made on three-month composites of aliquots from weekly samples. Beginning November 1962 the frequency of strontium–90 analyses was reduced to twice a year at each sampling point except those stations immediately below nuclear installations. Until the fourth quarter of 1961, the method used for determining strontium–90 was that described in the above reference (*7*). Tributyl phosphate was used to extract ingrown yttrium–90 from the purified, coprecipitated strontium–90. Beginning with the first quarter of 1962, a modification of a procedure described by Harley has been used (*8*). The yttrium–90, together with an yttrium carrier, is precipitated at pH 8.5; the precipitate is washed, redissolved, and reprecipitated as yttrium oxalate and the latter is washed and counted in a low-background, anticoincidence, end-window proportional counter.

Results

Table 1 presents November 1963 results of alpha and beta analyses of U. S. surface waters. The stations on a river are arranged in the table according to their relative location on the river, the first station listed being closest to the headwaters. These data are preliminary. Replicate analyses of some samples as well as some analyses incomplete at the time of this report will be included in the System's Annual Compilation of Data (*6*). The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pc/liter. When all samples have zero pc/liter, the mean is reported as zero and when the calculated mean is between zero and 0.5 the mean is reported as <1 pc/liter. The most recent quarterly strontium–90 results appeared in the January 1964 *RHD* (*9*).

TABLE 1.—RADIOACTIVITY IN U.S. SURFACE WATERS, NOVEMBER 1963 [a]

(Average concentrations in pc/liter)

Station	Beta activity			Alpha activity		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Allegheny River:						
Pittsbugh, Pa	1	16	17	0	0	0
Animas River:						
Cedar Hill, N. Mex	4	28	32	0	2	2
Apalachicola River:						
Chattahoochee, Fla	2	8	10	0	0	0
Arkansas River:						
Coolidge, Kansas	10	41	51	1	25	26
Ponca City, Okla	18	33	51	1	3	4
Fort Smith, Ark	24	19	43	1	1	2
Little Rock, Ark	8	45	53	1	2	3
Pendleton Ferry, Ark	12	30	42	1	1	2
Bear River:						
Preston, Idaho	0	21	21	0	3	3
Big Horn River:						
Hardin, Mont	38	33	71	6	10	16
Big Sioux River:						
Sioux Falls, S. Dak	2	30	32	0	7	7
Chattahoochee River:						
Atlanta, Ga	4	8	12	0	0	0
Columbus, Ga	0	9	9	0	1	1
Lanett, Ala	1	7	8	0	0	0
Chena Slough:						
Fairbanks, Alaska	1	4	5	0	0	0
Clearwater River:						
Lewiston, Idaho	2	7	9	0	0	0
Clinch River:						
Clinton, Tenn	2	17	19	0	0	0
Kingston, Tenn	3	79	82	0	1	1
Colorado River:						
Loma, Colo	11	22	33	2	11	13
Page, Ariz	4	37	41	0	10	10
Boulder City, Nev	0	18	18	0	7	7
Parker Dam, Calif-Ariz	1	18	19	0	10	10
Yuma, Ariz	0	14	14	0	2	2
Columbia River:						
Northport, Wash	1	13	14	0	1	1
Wenatchee, Wash	1	13	14	0	0	0
Pasco, Wash	85	891	976	0	1	1
McNary Dam, Ore	39	312	351	0	<1	<1
Bonneville, Ore	7	217	224	0	1	1
Clatskanie, Ore	8	91	99	0	<1	<1
Cumberland River:						
Clarksville, Tenn	1	8	9	0	0	0
Connecticut River:						
Wilder, Vt	3	18	21	0	0	0
Northfield, Mass	29	15	44	1	0	1
Enfield Dam, Conn	4	14	18	0	0	0
Cuyahoga River:						
Cleveland, Ohio	5	35	40	<1	0	<1
Delaware River:						
Martins Creek, Pa	1	10	11	0	0	0
Trenton, N. J	6	10	16	1	0	1
Philadelphia, Pa	4	13	17	0	0	0
Escambia River:						
Century, Fla	1	6	7	0	0	0
Great Lakes:						
Duluth, Minn	1	5	6	0	0	0
Sault Ste. Marie, Mich	0	5	5	0	0	0
Milwaukee, Wisc	1	7	8	0	0	0
Gary, Ind	1	9	10	0	0	0
Port Huron, Mich	1	9	10	0	0	0
Detroit, Mich	0	9	9	0	0	0
Buffalo, New York	8	14	22	0	0	0
Green River:						
Dutch John, Utah	1	38	39	0	0	0
Hudson River:						
Poughkeepsie, N. Y	2	25	27	0	0	0
Illinois River:						
Peoria, Ill	0	25	25	0	2	2
Grafton, Ill	81	23	104	4	2	6
Kanawha River: Winfield Dam, W. Va	1	13	14	0	1	1
Kansas River:						
De Soto, Kansas	34	36	70	3	2	5
Klamath River:						
Keno, Oreg	1	19	20	0	0	0
Little Miami River:						
Cincinnati, Ohio	0	13	13	0	0	0
Maumee River:						
Toledo, Ohio	14	21	35	3	1	4
Merrimack River:						
Lowell, Mass	4	19	23	0	0	0
Mississippi River:						
St. Paul, Minn	4	25	29	0	1	1
Dubuque, Iowa	1	25	26	0	1	1
Burlington, Iowa	4	24	28	0	1	1
E. St. Louis, Ill	18	32	50	0	2	2
Cape Girardeau, Mo	21	29	50	2	2	4
W. Memphis, Ark	2	26	28	0	2	2
Vicksburg, Miss	5	23	28	1	1	2
Delta, La	4	22	26	0	1	1
New Orleans, La	1	23	24	0	1	1
Missouri River:						
Williston, N. Dak	5	23	28	0	4	4
Bismarck, N. Dak	2	36	38	0	4	4
Yankton, S. Dak	0	31	31	0	5	5
Omaha, Nebr	8	22	30	1	3	4
St. Joseph, Mo	13	26	39	3	5	8
Kansas City, Kans	14	26	40	2	4	6
Missouri City, Mo	7	27	34	0	1	1
St. Louis, Mo	11	24	35	1	2	3
Monongahela River:						
Pittsburgh, Pa	0	21	21	0	1	1
North Platte River:						
Henry, Nebr	9	44	53	0	28	28
Ohio River:						
Toronto, Ohio	6	20	26	1	0	1
Addison, Ohio	3	22	25	0	0	0
Huntington, W. Va	1	21	22	0	0	0
Cincinnati, Ohio	1	25	26	0	0	0
Louisville, Ky	0	24	24	0	1	1
Evansville, Ind	2	24	26	0	0	0
Cairo, Ill	0	19	19	0	0	0
Ouachita River:						
Bastrop, La	4	20	24	0	3	3
Pend Oreille River:						
Albeni Falls Dam, Idaho	0	9	9	0	0	0
Platte River:						
Plattsmouth, Nebr	34	33	67	3	4	7
Potomac River:						
Williamsport, Md	1	11	12	0	0	0
Great Falls, Md	1	13	14	0	1	1
Washington, D.C	2	12	14	<1	0	<1
Rainy River:						
Baudette, Minn	5	30	35	0	0	0
International Falls, Minn	2	32	34	0	0	0
Raritan River:						
Perth Amboy, New Jersey (5-ft. Below Surface)	4	13	17	0	4	4
Perth Amboy, New Jersey (5-ft. Above Bottom)	1	11	12	0	4	4
Red River, North:						
Grand Forks, N. Dak	0	48	48	0	1	1
Red River, South:						
Denison, Tex	2	45	47	0	0	0
Index, Ark	2	33	35	0	0	0
Bossier City, La	1	25	26	0	1	1
Alexandria, La	2	33	35	0	1	1
Rio Grande River:						
Alamosa, Colo	4	14	18	0	0	0
El Paso, Tex	2	28	30	0	1	1
Laredo, Tex	123	21	144	19	5	24
Brownsville, Tex	3	20	23	0	1	1
Roanoke River:						
John H. Kerr Resr/Dam, Va	0	8	8	0	0	0
Sabine River:						
Ruliff, Tex	123	21	144	0	0	0
Sacramento River:						
Courtland, Calif	4	8	12	0	0	0
St. Lawrence River:						
Massena, N. Y	1	13	14	0	0	0
San Joaquin River:						
Vernalis, Calif	6	20	26	0	1	1
San Juan River:						
Shiprock, N. Mex	29	31	60	4	13	17
Savannah River:						
North Augusta, S. C	1	9	10	0	0	0
Port Wentworth, Ga	3	14	17	0	0	0
Schuylkill River:						
Philadelphia, Pa	1	17	18	0	0	0
Shenandoah River:						
Berryville, Va	1	10	11	0	1	1
Ship Creek:						
Anchorage, Alaska	0	4	4	0	0	0
Snake River:						
Ice Harbor Dam, Wash	1	13	14	0	3	3
Wawawai, Wash	9	14	23	0	3	3
Payette, Idaho	2	19	21	0	5	5
South Platte River:						
Julesburg, Colo	35	99	134	3	31	34
Spokane River:						
Post Falls, Idaho	0	6	6	0	0	0
Susquehanna River:						
Sayre, Pa	2	9	11	1	1	2
Conowingo, Md	0	16	16	0	0	0
Tennessee River:						
Lenoir City, Tenn	1	14	15	0	0	0
Chattanooga, Tenn	2	13	15	0	0	0
Bridgeport, Ala	0	10	10	0	0	0
Pickwick Landing, Tenn	3	16	19	0	0	0
Tombigbee River:						
Columbus, Miss	3	8	11	1	0	1
Truckee River:						
Farad, Calif	3	9	12	0	0	0
Verdigris River:						
Nowata, Okla	0	37	37	0	0	0
Wabash River:						
New Harmony, Ind	7	15	22	1	1	2
Willamette River:						
Portland, Oreg	2	6	8	0	0	0
Yakima River:						
Richland, Wash	0	11	11	0	3	3
Yellowstone River:						
Sidney, Mont	11	24	35	1	2	3
Maximum	123	891	976	19	31	34
Minimum	0	4	4	0	0	0

[a] These data are preliminary; reanalysis of some samples may be made and additional analysis not completed at the time of the report may become available. For final data, one should consult the Network's *Annual Compilation of Data* (6).

In order to obtain a geographical perspective of the radioactivity in surface water, the numbers alongside the various stations in figure 1 give the November 1963 average total beta activity in suspended-plus-dissolved solids in raw water collected at that station. Results for the years 1957–1962 have been summarized by Weaver *et al* (*10*).

Discussion

The monthly dissolved beta activity averages exceeded 200 pc/liter only on the Columbia River. Of the six stations on the Columbia River, the four downstream from the Hanford Atomic Products Operations facility had averages of between 91 and 891 pc/liter. It can be observed that the concentration diminishes with distance downstream from the facility.

While there are no generally applicable standards for surface water, the radioactivity associated with dissolved solids provides a rough indication of the levels which could occur in treated water, since nearly all suspended matter is removed by the treatment process (*11*). The Public Health Service Drinking Water Standards state that in the absence of strontium-90 and alpha emitters,[1] a water supply is acceptable when the gross beta concentration does not exceed 1000 pc/liter (*12*).

REFERENCES

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(*2*) *Ibid.*, 1959 Edition. Price $1.75.

(*3*) *Ibid.*, 1960 Edition.[2]

(*4*) *Ibid.*, 1961 Edition.[2]

(*5*) *Ibid.*, 1962 Edition.[2]

(*6*) *Ibid.*, 1963 Edition (in press).

(*7*) American Public Health Association, American Water Works Association and Water Pollution Control Federation: *Standard Methods for the Examination of Water and Wastewater*, 11th Edition, New York (1960).

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(*9*) Public Health Service: National Water Quality Network, July 1963, *Radiological Health Data, 5*: 31-35, (January 1964).

(*10*) Weaver, L., A. W. Hoadley, and S. Baker: Radioactivity in Surface Waters of the United States, 1957-1962, *Radiological Health Data, 4*:306-16, (June 1963).

(*11*) Straub, C. P.: Significance of Radioactivity Data, *Journal of the American Water Works Association, 53*:704 (June 1961).

(*12*) Public Health Service: *Drinking Water Standards, Revised 1962, Public Health Service Publication No. 956*, Superintendent of Documents, Government Printing Office, Washington D.C. 20402 (March 1963), price 30 cents.

[1] Absence is taken here to mean a negligibly small fraction of the specific limits of 3 pc/liter and 10 pc/liter for unidentified alpha emitters and strontium-90, respectively.

[2] Single free copies of this publication may be obtained from: Public Inquiries Branch, Public Health Service, U. S. Department of Health, Education, and Welfare, Washington, D. C. 20201.

Section IV—Other Data

STRONTIUM-90 CONTENT OF HUMAN BONES (1961-1963)

Edward S. Weiss, William H. Land, Kenneth H. Falter, and Robert M. Hallisey[1]

Introduction

Even before its production in large quantities, strontium–90 was recognized as a potentially hazardous radionuclide because of its biochemical characteristics and physical behavior. With the advent of high yield weapons testing, Project Sunshine was established to examine more intensively the hazards to man of radioactive debris. The project report (*1*) confirmed an earlier conclusion that strontium–90 was the nuclide of major interest because:

(a) strontium–90, introduced into soil and plants from nuclear weapons tests, finds its way through the food chain to human beings;

(b) when ingested by people, strontium–90 seeks the skeleton and there remains for a period of years; and

(c) infants and children, because of their rapid growth, constitute the critical segment of the population with respect to uptake and retention of this nuclide.

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The Project Sunshine report recommended adoption of a sampling program for collection and radiochemical analysis of human bone. Kulp and his associates at the Lamont Geological Observatory actively pursued this proposal, and they first detected environmental strontium–90 in animal bones and in milk products in July 1953.

In 1957, this group reported an average concentration of 0.1 pc strontium–90 per gram of calcium in human beings of all ages for the year 1955 (*2*). The work at Lamont on the geochemistry and biochemistry of strontium–90 still continues although the human bone phase was terminated in 1961, marked by the publication of the three volumes of "Strontium–90 in Man and His Environment" (*3*).

In March 1961, the Health and Safety Laboratory of the Atomic Energy Commission began collecting human bones in the three cities (New York, Chicago and San Francisco) where diet surveillance had been started in 1960 (*4,5*).

In order to permit more intensive study of variations of the concentration of strontium–90 in man by age and geographical region, the Public Health Service began collecting specimens in late 1961. This report describes and presents the Public Health Service experience and laboratory results for persons who died between November 1961 and August 1963.

Collection

Pathologists, medical examiners and coroners in large cities were invited to submit human bone specimens by mail. The samples have been obtained in the main from deceased persons, with a small number from living persons as a result of amputations or other surgical procedures. In areas with high population density or elevated environmental strontium-90 levels, efforts to increase participation have been intensified. As a result, about 30 participants in the PHS program have each submitted at least 10 specimens meeting the requirements with respect to age, quantity and cause of death, and another 150 have each provided one or two acceptable specimens.

The target population consists of children and young adults up to 25 years of age. Since strontium-90 in measureable amounts has been present in the global environment for only about 10 years and major calcium accretion ends by age 17 or 18, persons over 25 years of age are of limited interest for this program.

The specimens desired are from persons who were victims of accidents or of an acute disease process that was not likely to impair bone metabolism. The minimum quantity required for an individual laboratory analysis is about 100 grams of wet bone, which is easily obtained from older children but presents some difficulties in infants and children under five years of age.

The most readily obtainable specimens are vertebrae and ribs. Rivera at HASL has restricted his published results to vertebrae and focuses his collection efforts on this type of bone (*4,5*). It has been found unfeasible to collect long bones in sufficient numbers for direct comparison of results although British investigators have been successful in procuring long bones in quantity. Ribs and vertebrae, being less dense and presumably in a more dynamic state with respect to calcium exchange rate, yield results that may have to be adjusted to provide estimates of the skeletal burden of radiostrontium in older children and in adults.

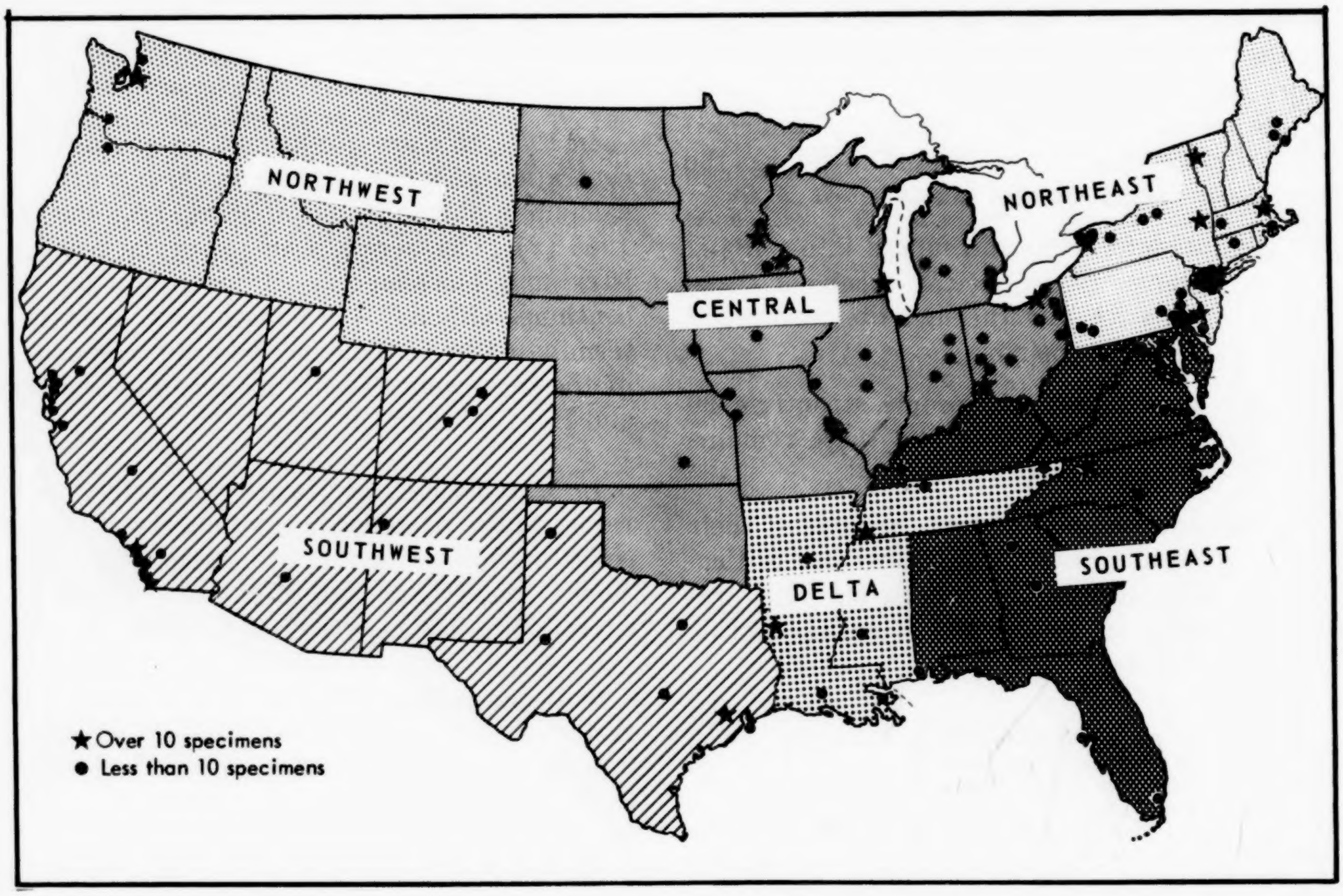

FIGURE 1.—REGIONS FOR PHS BONE SAMPLING PROGRAM AND LOCATION OF COLLECTION CENTERS

For the purposes of this study, the country has been divided into six geographical regions as shown in figure 1. These regions represent an attempt to combine some elements of climatic and topographic homogeneity with the patterns of strontium–90 in the local diet as reflected by the 63 stations in the Public Health Service Pasteurized Milk Network. The locations of bone collection stations are indicated by the symbols superimposed on the figure.

The general characteristics of the 903 specimens collected in the first two years' operations are presented in table 1. Over 600 specimens are suitable for individual analysis and of these, over 400 are in the preferred age group. The specimens weighing less than 100 grams may be pooled in appropriate age groups by region to secure intrinsically useful information or they may be randomly pooled in large quantities for quality control standards. The major deficiencies are in the Mississippi delta region, where the highest strontium–90 concentrations in milk have been observed from time to time, and in the Northwest, where high milk levels followed the last series of weapons tests by the U. S. and the U.S.S.R.

TABLE 1.—SUMMARY OF BONE SPECIMENS RECEIVED

Region	Age of patient at time of death					
	Up to 25 years			25 years and older		
	Less than 100 g.	100 g. or more	Total	Less than 100 g.	100 g. or more	Total
Northeast	44	100	144(24%)	6	86	92(31%)
Southeast	14	44	58(9%)	8	59	67(23%)
Central	77	198	275(45%)	47	38	85(29%)
Delta	10	20	30(5%)	1	8	9(3%)
Northwest	15	20	35(6%)	0	11	11(4%)
Southwest	35	32	67(11%)	8	22	30(10%)
Totals (903)	195	414	609	70	224	294

To supplement the limited information obtained with the specimens, copies of birth and death certificates of each individual will be obtained. This will permit grouping the laboratory results by cause of death, duration of residence in a region, and by socio-economic class as indicated by the father's occupation.

Laboratory Procedures

The bones are ashed in two stages at 800°C in aluminum oxide crucibles at the Northeastern Radiological Health Laboratory at the Division of Radiological Health, at Winchester, Massachusetts. The procedure (*6*) for extracting the strontium–90 and measuring its yttrium–90 daughter involves the following steps:

1. The ash is dissolved in 6*N* hydrochloric acid and made up to 500 ml volume.
2. Approximately 40 mg of yttrium carrier are added to a 200-ml aliquot, the pH is adjusted to 1.0 with ammonium hydroxide and approximately 80 ml of 1*N* oxalic acid is added to precipitate the calcium-strontium-yttrium fraction as the oxalate.
3. The solution is filtered through Whatman #42 filter paper using suction and the precipitate on the filter paper is transferred to a platinum crucible and ignited (Meker burner for 1 hour). The oxalate precipitate is thus converted to the hydroxide-carbonate form.
4. The hydroxide-carbonate precipitate is redissolved in 3*N* nitric acid, adjusted to a pH of 1 with ammonium hydroxide and approximately 80 ml of oxalic acid solution is again added to precipitate yttrium as the oxalate. Step three is repeated.
5. The hydroxide-carbonate precipitate is then dissolve in 3*N* nitric acid and boiled to remove CO_2.
6. The yttrium is precipitated as the hydroxide with ammonium hydroxide and purified by a series of solution-precipitation steps with hydrochloric acid and ammonium hydroxide. This is done until no more calcium carbonate precipitate is observed when sodium carbonate is added to the supernatant liquid portion from the hydroxide precipitation. This requires three to five precipitation steps.
7. The precipitate is dissolved in concentrated hydrochloric acid and the pH is brought to 5 with an acetate buffer solution. Approximately 10 to 20 ml of 0.5*M* 2–thenoyltrifluoroacetone (TTA) in benzene is added. The mixture is extracted for 5 minutes, the layers are allowed to separate, the aqueous phase is drawn off into another separatory funnel, and another 10–20 ml of TTA solution is added. The mixture is ex-

tracted and the layers are allowed to separate. The two TTA solutions are combined and the aqueous phase is discarded.

8. The TTA-benzene is stripped with 0.1N nitric acid (pH 1). Approximately 10 ml of 1M oxalic acid is added to precipitate the yttrium as the oxalate. The precipitate is collected on glass fiber filter paper, dried, and weighed for chemical yield. The samples were originally counted for 30 minutes with a low background beta counter with automatic sample changer. Starting in September 1963 the counting time was increased to 100 minutes and the samples were counted without the automatic sample changer for 10 minutes.
9. Calculations:

$$S=\frac{(G-B)V}{2.22EADC}, \text{ where} \qquad \text{(Eq. 1)}$$

S = activity of Sr^{90} in sample, pc

G = gross (sample + background) counting rate, cpm

B = background counting rate, cpm

V = volume to which ash solution is diluted (usually 500 ml)

E = counting efficiency, count/disintegration

A = volume taken for aliquot (usually 200 ml)

D = decay factor for Y^{90} from separation (step 2) to counting

C = chemical yield

2.22 = conversion factor, dpm per picocurie, and

$$CE=\frac{1.96\left(\frac{G}{t_g}+\frac{B}{t_b}\right)^{1/2}V}{2.22EADC}, \text{ where} \qquad \text{(Eq. 2)}$$

CE = counting error at 95 percent confidence level, pc

t_g = counting time over which gross counting rate is determined, minutes

t_b = counting time over which background is determined, minutes; the other symbols have the same meanings as above

Results

The results of the 199 individual laboratory analyses on 194 bone specimens (four duplicate analyses) analyzed through October 1963 are summarized in table 2 and given in detail in table 3. In age groups above 0–4 years, the 1963 average values are slightly higher than the 1.0 to 3.2 pc per gram of calcium observed in the previous year. Conversely, the average for the lowest age group has dropped from 4.2 to 3.2 pc per gram in the same period.

The highest bone concentration, 9.7 pc per gram of calcium, was reported for a 1½ year old child in the northeastern region of the U. S.

TABLE 2.—ANALYSES OF STRONTIUM-90 IN BONE, BY AGE AND REGION

[pc Sr^{90}/g calcium]

Region	0–4 yrs.				5–9 yrs.				10–14 yrs.				15–19 yrs.				20–24 yrs.				25+ yrs.				Total No.
	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	
	1961–1962 Deaths																								
Northeast	4.8	1.6	9.7	9	5.1	2.4	9.4	7	2.4	1.4	3.2	7	2.8	1.1	4.6	7	2.1	1.3	4.9	12	1.1	0.9	1.6	3	45
Southeast	5.8	5.2	6.3	2	3.4	3.4	3.4	1	2.5	2.0	3.0	2	2.5	1.9	3.0	4	1.8	1.4	2.2	7	[a]—	—	—	—	16
Central	2.8	1.7	3.9	7	2.2	1.4	2.7	6	2.2	1.2	3.5	8	2.0	1.2	3.4	7	1.6	0.9	2.6	8	0.8	0.8	0.8	1	37
Delta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.8	1.6	2.0	2	—	—	—	—	2
Northwest	2.9	2.9	2.9	1	—	—	—	—	2.1	1.8	2.6	3	1.8	1.3	2.4	4	1.7	1.4	2.4	3	—	—	—	—	11
Southwest	4.9	3.0	6.8	2	1.7	1.7	1.7	1	—	—	—	—	3.0	3.0	3.0	1	0.9	0.9	0.9	1	—	—	—	—	5
All	4.2	1.6	9.7	21	3.6	1.4	9.4	15	2.3	1.2	3.5	20	2.3	1.1	4.6	23	1.8	0.9	4.9	33	1.0	0.8	1.6	4	116
	1963 Deaths																								
Northeast	3.6	1.2	5.7	4	4.2	3.4	5.5	5	3.6	2.3	5.7	4	3.0	1.6	4.8	19	2.2	1.6	3.1	12	2.4	1.7	3.0	2	46
Southeast	1.9	1.9	1.9	1	—	—	—	—	2.0	2.0	2.0	1	3.9	3.9	3.9	1	1.9	1.5	2.4	4	1.8	1.8	1.8	1	8
Central	3.0	2.4	4.2	8	4.2	4.2	4.2	1	2.3	1.7	3.6	10	2.2	1.4	2.7	3	5.0	5.0	5.0	1	—	—	—	—	23
Delta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Northwest	4.1	3.5	4.7	2	2.4	2.2	2.6	2	3.8	1.8	5.9	2	—	—	—	—	—	—	—	—	—	—	—	—	6
Southwest	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
All	3.2	1.2	5.7	15	3.8	2.2	5.5	8	2.8	1.7	5.9	17	2.9	1.4	4.8	23	2.3	1.5	5.0	17	2.2	1.7	3.0	3	83

[a] Dash indicates no sample received.

TABLE 3.—DETAILS OF INDIVIDUAL BONE SAMPLES AND RESULTS OF STRONTIUM-90 ANALYSES

State and sample no.	Types of bone [a]	Date of death	Age	Sex	Original weight (g)	Ash weight (g)	pc Sr^{90}/g of		
							Ash ($+2\sigma$CE) [b]	Ca	Bone
Calif.									
IX-8 (0003)	V	10/15/62	20y9m3d	F	273.2	40.8	0.34 ±0.07	0.88	0.05
IX-8 (0004)	V	11/6/62	8y4m4d	F	138.1	14.7	0.65 ±0.06	1.69	0.07
IX-8 (0007)	V	12/4/63	17y1m3d	F	204.2	31.1	1.15 ±0.28	3.01	0.17
D. C.									
III-3 (0001)	I V	11/5/62	10y7m	M	115.1	21.7	0.75 ±0.11	2.05	0.15
III-4 (0004)	V	1/7/63	25y1m	F	103.8	14.9	0.63 ±0.14	1.81	0.10
La.									
VII-6 (0001) [c]	V R	10/15/62	24y	M	223.1	42.0	0.70 ±0.13	2.00	0.15
VII-6 (0001) [c]	V R	10/15/62	24y	M	223.1	42.0	0.55 ±0.12	1.56	0.11
Maine									
I-9 (0001)	V S	6/9/63	19y	M	237.6	11.7	1.53 ±0.29	4.70	0.08
Md.									
III-1 (0008)	V	8/4/62	2y	M	95.0	8.1	2.11 ±0.36	5.25	0.18
III-1 (0026)	V	10/22/62	23y4m	M	110.9	14.3	0.62 ±0.14	1.75	0.09
III-6 (0002)	V S F T	1/6/63	3d	M	97.5	17.0	0.77 ±0.14	1.93	0.13
III-7 (0001)	V	11/16/62	19y	M	149.2	20.3	1.16 ±0.19	3.02	0.16
III-7 (0003)	V	11/16/62	16y	M	120.3	17.4	0.77 ±0.16	2.16	0.12
III-7 (0004)	V	11/15/62	16y	M	157.7	24.4	0.69 ±0.11	1.92	0.11
III-7 (0005)	V	11/26/62	22y	M	132.9	21.4	0.80 ±0.11	2.17	0.13
III-7 (0006)	V	10/8/62	20y	M	141.0	18.7	0.70 ±0.14	2.01	0.10
III-7 (0008)	V	10/28/62	1y6m	M	95.6	9.0	2.02 ±0.43	6.27	0.19
III-7 (0009)	V	10/8/62	16y	M	158.9	22.3	0.97 ±0.14	2.79	0.14
III-7 (0010)	V	10/30/62	11y	M	145.3	15.5	1.06 ±0.23	3.03	0.12
III-7 (0011) [c]	V	11/11/62	21y	M	90.2	13.9	0.51 ±0.15	1.48	0.09
III-7 (0011) [c]	V	11/11/62	21y	M	90.2	13.9	0.48 ±0.12	1.41	0.08
III-7 (0013)	V	12/9/62	22y	M	208.5	15.8	0.84 ±0.18	2.16	0.06
III-7 (0014)	V	1/9/63	13y	M	158.4	15.5	0.74 ±0.16	1.99	0.07
III-7 (0015)	V	2/28/63	22y	M	156.6	23.4	0.58 ±0.11	1.52	0.09
III-7 (0017)	V	3/31/63	22y	M	112.6	14.8	0.70 ±0.17	1.84	0.09
III-7 (0018)	V	3/3/63	21y	M	162.0	20.9	0.91 ±0.10	2.38	0.12
III-7 (0019)	V	3/23/63	20y	F	123.6	23.6	0.71 ±0.08	1.97	0.15
III-7 (0020)	V	2/5/63	16y	M	110.3	12.9	1.29 ±0.21	3.89	0.17
III-7 (0021)	V	2/21/63	Unknown	M	127.3	21.9	0.65 ±0.13	1.83	0.12
III-7 (0023)	V	12/17/62	6y	F	114.5	11.5	1.24 ±0.26	3.38	0.12
Mass.									
I-1 (0002)	V	9/19/62	10y	M	166.2	14.4	0.81 ±0.18	2.11	0.07
I-1 (0003)	V	9/30/62	33y	F	172.7	22.9	0.27 ±0.08	0.86	0.04
I-1 (0004)	V S	12/30/62	1y7m	M	87.5	6.7	3.39 ±0.55	9.68	0.26
I-1 (0006)	V S	3/5/63	20y	M	207.4	36.0	0.98 ±0.10	2.50	0.17
I-1 (0007)	V S	4/22/63	14y	F	143.8	11.9	1.18 ±0.24	3.30	0.10
I-1 (0008)	V S	5/6/63	6y	M	93.5	7.3	1.27 ±0.21	4.06	0.11
I-1 (0009)	V	6/5/63	19y	M	263.8	36.6	1.10 ±0.11	2.94	0.15
I-2 (0001)	V	7/26/62	15y7m	M	159.4	23.0	1.47 ±0.22	3.86	0.21
I-2 (0004)	V R	6/21/63	16y9m	F	100.1	9.2	1.01 ±0.18	2.98	0.09
I-2 (0005)	V	6/19/63	4y	M	97.5	8.4	1.98 ±0.23	5.72	0.17
I-2 (0008)	V	7/2/63	8y	F	158.3	14.9	1.31 ±0.21	3.65	0.12
I-2 (0009)	V	7/2/63	6y	M	151.8	10.8	1.57 ±0.18	4.37	0.11
I-2 (0014)	V	8/1/63	9y	F	222.0	12.6	1.85 ±0.28	5.48	0.11
I-2 (0017)	V	7/30/63	10y	M	100.4	10.3	1.95 ±0.21	5.69	0.21
I-3 (0001)	V R	11/8/62	6y	F	147.3	15.1	3.34 ±0.32	9.4	0.34
I-3 (0002)	V	10/3/62	17y8m	M	146.4	15.3	0.94 ±0.23	2.53	0.10
I-5 (0001)	V R	12/2/62	20y	M	78.6	11.6	0.63 ±0.16	1.7	0.09
I-5 (0002)	V R	12/5/62	20y	F	133.0	24.3	0.76 ±0.13	1.9	0.14
I-7 (0001)	V R	11/18/62	19y	M	132.2	16.9	0.46 ±0.14	1.12	0.06
I-7 (0002)	V R	11/30/62	2y	F	53.9	4.5	2.98 ±0.58	8.3	0.25
I-7 (0003)	V R	2/22/63	14y	M	114.2	21.1	1.23 ±0.20	3.10	0.23
I-7 (0004)	V	3/9/63	18y	M	220.7	29.4	0.91 ±0.13	2.37	0.12
Mich.									
V-5 (0002)	V	1/17/63	2y2m16d	F	102.9	9.1	1.31 ±0.14	3.60	0.12
V-5 (0003)	V	2/11/63	22y6m12d	M	245.0	34.2	1.89 ±0.05	4.98	0.26
V-5 (0004)	V	4/18/63	10y3m7d	M	197.5	21.7	1.08 ±0.16	2.83	0.12
V-13 (0001)	V	10/19/62	22y11m12d	M	221.5	26.8	0.42 ±0.10	1.13	0.05
V-13 (0003)	V	10/24/62	19y5m13d	F	156.0	17.8	0.81 ±0.16	2.16	0.09
V-13 (0004)	V	11/6/62	24y11m16d	F	230.5	26.6	0.95 ±0.17	2.45	0.07
V-13 (0006)	V	11/22/62	19y 20d	M	142.6	16.8	1.28 ±0.15	3.37	0.24
V-13 (0007)	V	11/22/62	24y10m25d	M	130.4	17.4	0.57 ±0.15	1.49	0.08
V-13 (0008)	V	12/1/62	15y8m23d	F	152.5	21.7	0.46 ±0.12	1.17	0.07
V-13 (0009)	V	12/14/62	21y7m	M	139.2	22.4	1.01 ±0.16	2.59	0.16
V-13 (0010)	V	12/14/62	19y10m13d	M	116.9	15.9	0.61 ±0.16	1.55	0.08
Minn.									
VI-1 (0001)	V R S	10/20/62	9y2m	F	177.9	17.6	0.99 ±0.20	2.71	0.10
VI-1 (0005)	V S	1/16/63	10y5m27d	F	181.8	20.5	1.30 ±0.17	3.59	0.15
VI-6 (0003) [c]	V S	11/14/62	21y9m11d	M	251.8	32.7	0.33 ±0.09	0.87	0.04
VI-6 (0003) [c]	V S	11/14/62	21y9m11d	M	251.8	32.7	0.38 ±0.08	1.00	0.05
Mo.									
VI-2 (0002)	R	8/4/62	36y5m	M	50.6	16.0	0.30 ±0.12	0.79	0.10

[a] Type of bone: I, ilium; F, femur; Fi, fibula; R, rib; S, sternum; Sk, skull; V, vertebra.
[b] Two standard deviation counting error.
[c] Duplicate analysis.

TABLE 3.—DETAILS OF INDIVIDUAL BONE SAMPLES AND RESULTS OF STRONTIUM-90 ANALYSES—Continued

State and sample no.	Types of bone [a]	Date of death	Age	Sex	Original weight (g)	Ash weight (g)	pc Sr^{90}/g of Ash ($\pm 2\sigma$CE) [b]	pc Sr^{90}/g of Ca	pc Sr^{90}/g of Bone
N. Y.									
II-9 (0002)	V I F T Fi	9/30/62	1d	M	193.8	16.4	0.74±0.18	2.04	0.06
II-10 (0001)	V	11/11/62	21y3m	F	149.7	20.4	0.72±0.14	1.89	0.10
II-10 (0004)	V	1/1/63	18y3m	M	173.6	23.7	0.68±0.11	1.99	0.10
II-10 (0006)	V	1/24/63	25y8m	M	167.8	19.2	1.08±0.20	2.98	0.12
II-10 (0007)	V	4/12/63	16y9m	M	188.8	23.9	1.10±0.15	3.00	0.14
II-12 (0001)	V	7/31/62	20y	M	158.2	19.4	0.64±0.13	1.70	0.08
II-12 (0003)	V	10/11/62	16y7m	M	174.0	23.1	1.17±0.82	3.09	0.15
II-12 (0004)	V	10/6/62	20y1m	M	165.0	21.7	1.17±0.21	2.13	0.15
II-12 (0005)	V	12/30/62	10y11m5d	M	157.4	13.7	0.88±0.20	2.55	0.08
II-12 (0006)	V	2/4/63	21y11m	M	176.9	20.2	0.73±0.14	2.01	0.08
II-12 (0007)	V	2/23/63	19y6m	F	154.9	17.3	1.65±0.29	4.43	0.18
II-12 (0008)	V	3/5/63	19y4m	M	156.8	15.4	1.24±0.20	3.49	0.12
II-12 (0009)	V	3/20/63	18y11m7d	M	140.5	17.4	0.82±0.16	2.17	0.10
Ohio									
V-1 (0001)	V	8/4/62	6y6d	M	164.5	17.6	0.93±0.17	2.74	0.10
V-1 (0002)	V	8/10/62	18y7m10d	M	171.5	25.9	0.86±0.04	2.14	0.13
V-1 (0003)	V	9/3/62	23y3m	M	151.6	17.4	0.61±0.52	1.67	0.07
V-1 (0004)	V	10/15/62	17y2m2d	M	203.7	24.2	0.75±0.13	2.02	0.09
V-1 (0005)	V	1/16/63	14y1m27d	M	273.1	30.8	1.04±0.04	2.72	0.12
V-1 (0006)	V	1/31/63	14y3m6d	F	333.2	40.5	1.01±0.04	2.61	0.12
V-7 (0001)	V	10/19/62	11y4m29d	M	149.0	14.4	1.11±0.20	3.15	0.11
V-7 (0002)	V	10/9/62	21y7d	M	160.7	22.4	0.64±0.12	1.76	0.09
V-16 (0002)	V	1/16/63	19y6m29d	M	111.0	18.5	1.02±0.05	2.57	0.17
V-16 (0003)	V	1/15/63	10y11m15d	F	70.1	8.7	0.53±0.14	1.71	0.07
V-16 (0005)	V	2/17/63	19y2m10d	M	107.6	17.2	0.50±0.14	1.38	0.08
V-17 (0001)	V	12/10/62	12y1m4d	M	95.0	14.1	1.33±0.23	3.47	0.20
V-17 (0003)	V	1/8/63	12y4m9d	M	168.5	17.8	0.57±0.14	1.85	0.07
V-17 (0004) [c]	V	2/10/63	11y7m14d	F	219.3	23.8	0.52±0.12	1.67	0.07
V-17 (0004) [c]	V	2/10/63	11y7m14d	F	219.3	23.8	0.56±0.11	1.77	0.07
V-17 (0005)	V	3/22/63	16y	M	268.7	26.0	0.95±0.14	2.66	0.10
V-19 (0001)	V R Sk	11/20/61	3m	M	107.1	9.8	1.02±0.10	2.96	0.10
V-19 (0002)	V R S	11/25/61	3m	M	110.5	10.8	0.61±0.16	1.75	0.06
V-19 (0004)	V	12/9/61	14y	M	249.1	28.6	1.09±0.05	2.79	0.14
V-19 (0005)	V R	12/8/61	1y	M	141.3	11.9	1.16±0.19	3.37	0.10
V-19 (0006)	V	12/8/61	12y	F	269.3	33.7	0.60±0.08	1.60	0.08
V-19 (0008)	V R	12/23/61	10y	M	200.7	19.1	0.41±0.10	1.20	0.04
V-19 (0010)	V R	12/28/61	5y	M	263.8	20.8	0.91±0.14	2.74	0.08
V-19 (0011)	V R	12/26/61	10y	F	215.1	20.3	0.57±0.10	1.71	0.06
V-19 (0013)	V R	1/4/62	13y	F	276.8	33.2	0.17±0.02	2.45	0.02
V-19 (0014)	V R	1/5/62	2y	M	161.3	12.5	0.73±0.15	2.10	0.06
V-19 (0015)	V R	1/15/62	4y	M	226.7	20.5	1.26±0.17	3.81	0.12
V-19 (0035)	V R Sk	4/11/62	1d	M	90.4	14.8	0.62±0.05	1.75	0.12
V-19 (0036)	V	5/23/62	15y1m	M	203.8	24.2	0.56±0.09	1.70	0.07
V-19 (0039)	V	5/31/62	7y6d	M	203.1	15.6	0.71±0.05	2.28	0.06
V-19 (0044)	V	7/14/62	14y6m	F	297.9	36.7	0.53±0.07	1.53	0.07
Pa.									
II-1 (0001)	V I	7/13/62	5y1m	F	153.5	15.6	2.28±0.32	6.01	0.23
II-1 (0003)	V R	7/27/62	2y10m	M	85.4	8.7	1.87±0.36	5.20	0.19
II-1 (0004)	V	9/1/62	3y	F	107.6	8.9	1.37±0.26	3.86	0.11
II-1 (0005)	V	11/16/62	8y11m	F	122.5	11.4	1.59±0.50	4.50	0.15
II-2 (0001) [c]	V	7/26/62	14y11m	M	327.3	23.6	0.90±0.13	2.30	0.07
II-2 (0001) [c]	V	7/26/62	14y11m	M	327.3	28.3	0.53±0.09	1.38	0.05
II-2 (0002)	V	8/2/62	13y11m	M	179.1	19.0	1.08±0.76	2.93	0.12
II-2 (0003)	V	8/11/62	6y6m	F	196.2	18.9	1.47±0.24	4.00	0.14
II-2 (0004)	V	8/27/62	6y3m20d	F	99.7	8.1	0.77±0.10	2.40	0.07
II-2 (0005)	V	10/2/62	9y8m6d	F	146.3	13.6	2.39±0.13	7.07	0.24
II-3 (0002)	V	2/1/63	20y4m25d	M	100.7	10.0	1.13±0.08	3.14	0.12
II-4 (0001)	V	7/18/62	25y11m	M	220.0	30.7	0.40±1.01	1.01	0.06
II-4 (0005)	V	8/12/62	18y3m	M	148.5	19.2	0.77±0.16	2.00	0.10
II-4 (0006)	V	8/23/62	9y10m	M	134.1	12.6	0.92±0.22	2.57	0.09
II-4 (0007)	V	10/14/62	1y4m29d	M	72.3	7.1	2.02±0.18	5.55	0.20
II-4 (0010)	V	11/30/62	22y1m8d	M	89.5	11.5	1.73±0.09	4.88	0.24
II-4 (0014)	V	1/23/63	19y4m17d	M	153.6	21.2	1.09±0.05	2.98	0.16
II-5 (0003)	V R F	7/29/62	2d	F	67.3	9.8	0.61±0.19	1.55	0.09
II-6 (0038)	V	1/9/63	17y3d	F	121.6	14.9	0.56±0.05	1.59	0.07
II-6 (0042)	V	2/12/63	17y10m17d	M	148.3	18.1	1.04±0.05	2.80	0.13
II-6 (0047)	V	2/25/63	4m8d	F	111.2	14.9	0.42±0.05	1.15	0.06
II-19 (0002)	V	10/18/62	10y2m	M	211.6	21.3	0.99±0.13	2.61	0.10
II-19 (0003)	V	10/13/62	25y3m	M	207.6	31.7	0.60±0.09	1.55	0.09
II-19 (0004)	V	11/1/62	23y1m	M	161.0	26.4	0.64±0.13	1.66	0.10
II-19 (0006)	V	11/2/62	14y9m	M	259.5	34.5	1.20±0.15	3.16	0.16
II-19 (0007)	V R	11/1/62	1d	F	199.9	17.1	1.47±0.23	4.05	0.13
II-19 (0009)	V	11/6/62	16y8m	M	146.5	13.3	1.68±0.26	4.64	0.15
II-19 (0010)	V R	11/6/62	4y11m	M	160.4	21.7	1.23±0.20	3.38	0.17

[a] Types of bone: I, ilium F, femur; Fi, fibula; R, rib; S, sternum; Sk, skull; V, vertebra.
[b] Two standard deviation counting error.
[c] Duplicate analysis.

TABLE 3.—DETAILS OF INDIVIDUAL BONE SAMPLES AND RESULTS OF STRONTIUM-90 ANALYSES—Continued

State and sample no.	Types of bone [a]	Date of death	Age	Sex	Original weight (g)	Ash weight (g)	pc Sr^{90}/g of		
							Ash ($+2\sigma$CE) [b]	Ca	Bone
Pa.—Continued									
II-19 (0011)	V	11/16/62	20y2m	M	166.8	28.2	0.91±0.14	2.50	0.16
II-19 (0012)	V	12/6/62	17y	M	179.8	25.1	0.72±0.12	2.07	0.11
II-19 (0013)	V	12/26/62	21y	M	166.3	20.8	0.82±0.13	2.35	0.11
II-19 (0014)	V	12/18/62	23y	M	209.0	33.5	0.45±0.07	1.32	0.08
II-19 (0015)	V	1/7/63	25y	M	145.7	22.9	0.63±0.00	1.74	0.11
II-19 (0016)	V	1/10/63	17y26d	M	208.7	34.6	1.05±0.04	2.89	0.18
II-19 (0018)	V R	1/19/63	1y11m	F	197.3	12.7	1.45±0.24	4.21	0.09
II-19 (0021)	V	2/18/63	22y	M	188.3	28.4	0.61±0.13	1.69	0.10
II-19 (0022)	V	2/23/62	16y11m	F	166.2	22.7	0.59±0.12	1.67	0.09
II-19 (0023)	V R	2/24/63	4y5m16d	F	123.7	9.5	1.22±0.12	3.34	0.09
II-19 (0025)	V	3/8/63	20y7m	M	156.5	24.1	0.82±0.04	2.38	0.14
II-19 (0028)	V	4/10/63	24y1m3d	F	173.4	25.7	0.83±0.04	2.28	0.13
II-19 (0029)	V	4/22/63	10y5m	M	92.6	11.6	0.76±0.22	2.31	0.10
II-19 (0030)	V	4/15/63	9y10m	M	145.7	16.4	1.15±0.15	3.45	0.14
II-19 (0031)	V	4/14/63	22y4m	M	144.1	20.5	0.74±0.12	2.10	0.14
Texas									
VII-1 (0001)	V R	7/15/62	4y10m13d	F	93.0	13.5	1.01±0.23	2.98	0.15
VII-1 (0002)	V R	7/17/62	1y3m16d	M	108.3	11.3	2.37±0.35	6.82	0.26
Vt.									
I-6 (0001)	V	10/28/62	22y	M	148.6	27.1	0.62±0.06	1.6	0.11
I-6 (0003)	V	11/25/62	22y	M	275.8	36.55	0.62±0.11	1.6	0.08
I-6 (0005)	V	12/20/62	17y	M	206.3	31.4	1.11±0.12	2.96	0.17
I-6 (0007)	V	1/18/63	17y	M	175.6	28.9	1.20±0.13	3.17	0.20
I-6 (0008)	V	2/5/63	22y	F	170.8	25.0	0.87±0.13	2.30	0.13
I-6 (0009)	V	4/4/63	22y	F	182.8	25.4	0.52±0.11	1.60	0.08
I-6 (0012)	V	4/17/63	18y	M	281.2	36.1	0.94±0.11	2.50	0.12
I-6 (0014)	V	4/29/63	18y	M	182.4	24.2	1.81±0.18	4.78	0.24
I-6 (0017)	V	6/1/63	21y	F	229.9	35.3	0.81±0.10	2.13	0.13
I-6 (0022)	V	6/18/63	23y	F	182.0	26.9	0.63±0.31	1.78	0.10
I-6 (0024)	V	8/23/63	23y	M	206.6	31.2	0.83±0.11	2.17	0.13
I-6 (0026)	V	7/5/63	15y	M	178.8	20.4	1.32±0.17	3.48	0.15
Va.									
III-5 (0001)	R V	12/18/62	20y	M	178.8	29.5	0.78±0.11	1.99	0.13
Wash.									
IX-3 (0004)	V	8/24/62	15y8m	F	87.1	16.5	0.95±0.17	2.41	0.18
IX-3 (0005)	V	8/31/62	12y6m	M	86.8	15.1	1.04±0.17	2.63	0.18
IX-3 (0006)	V	9/3/62	19y10m10d	M	178.7	23.3	0.52±0.14	1.32	0.07
IX-3 (0007)	V	9/17/62	14y6m	M	102.3	15.8	0.72±0.16	1.84	0.11
IX-3 (0008)	V	9/15/62	24y	F	113.8	23.2	0.50±0.09	1.36	0.11
IX-7 (0002)	V	10/1/62	16y6m2d	F	86.4	9.0	0.72±0.10	1.90	0.08
IX-7 (0007)	V	11/28/62	10y3m	M	164.7	12.8	0.71±0.16	1.96	0.06
IX-7 (0008)	V	12/7/62	4y11m	M	110.3	8.4	1.04±0.23	2.94	0.08
IX-7 (0009)	R V	12/12/62	13y11m	F	169.1	21.5	0.87±9.14	2.36	0.11
IX-7 (0010)	V	1/8/63	3y5m	M	119.8	11.4	1.67±0.26	4.72	0.16
IX-7 (0011)	V	1/15/63	2y4m	F	88.8	7.9	1.22±0.03	3.46	0.11
IX-7 (0012)	V	1/16/63	8y4m	M	174.1	16.5	0.94±0.18	2.59	0.09
IX-7 (0013)	V	1/22/63	7y4m	M	114.1	10.0	0.81±0.20	2.22	0.07
IX-7 (0014)	V	1/24/63	10y10m	M	128.7	13.0	0.61±0.15	1.84	0.06
IX-7 (0017)	V	3/9/63	14y1m10d	F	228.9	26.1	1.91±0.06	5.86	0.24
IX-10 (0001)	R I	11/13/62	22y5m	M	128.8	29.3	0.61±0.09	1.51	0.14
IX-10 (0002)	R	12/3/62	19y1m	M	89.5	22.1	0.59±0.12	1.46	0.15
Wisc.									
V-3 (0007)	V	12/10/62	2y3m9d	M	113.1	11.9	1.39±0.27	3.90	0.15
V-3 (0009)	V	1/8/63	3y1m20d	M	196.3	18.3	0.88±0.16	2.45	0.08
V-3 (0010)	V	1/8/63	3y5m18d	M	138.3	12.8	1.02±0.23	2.58	0.09
V-3 (0012)	V	1/20/63	3y10m25d	F	162.8	16.1	1.09±0.06	2.97	0.11
V-3 (0016)	V	2/21/63	2y5m2d	F	95.2	7.6	0.92±0.20	2.68	0.07
V-3 (0017)	V	2/25/63	5y2m5d	M	181.1	15.8	1.57±0.22	4.23	0.14
V-3 (0018)	V	3/4/63	1y7m23d	F	112.4	10.9	1.58±0.19	4.23	0.15
V-3 (0019)	V	3/1/63	10y1m	M	252.5	21.5	1.02±0.15	2.85	0.09
V-3 (0023)	V	3/5/63	2y5m8d	F	121.1	11.9	0.98±0.14	2.69	0.10
V-3 (0025)	V	3/21/63	4y9m1d	F	160.4	16.4	1.00±0.19	2.71	0.10
V-3 (0029)	V	3/31/63	10y6m2d	M	256.8	26.4	0.49±0.10	1.76	0.06
V-4 (0001)	V	10/6/62	8y8m21d	F	91.9	8.0	0.55±0.17	1.58	0.05
V-4 (0002)	V	10/23/62	8y10m5d	F	67.7	8.4	0.52±0.16	1.39	0.06

[a] Type of bone: I, ilium; F, femur; Fi, fibula; R, rib; S, sternum; Sk, skull; V, vertebra.
[b] Two standard deviation counting error.
[c] Duplicate analysis.

Discussion

The Federal Radiation Council (FRC) states (*7*) that "As a step in the development of guidance on *intake* of strontium-90, it is necessary to determine the average daily intake of strontium-90 which would correspond to doses of one-third the RPG's to be applied to suitable samples of an exposed population group." In its first report (*8*) the Council cautions that the use of a population average guide "is per-

missible only when there is a probability of appreciable homogeneity concerning the distribution of the dose within the population included in the average."

Since intake is related to dose on the basis of skeletal concentration, the Council states that "a continued dietary ratio of 200 pc of strontium–90 per gram of calcium is estimated to result in a skeletal concentration of 50 pc per gram of calcium and to produce radiation doses, averaged over any age group of a uniformly exposed population group, corresponding to approximately one-third of the appropriate RPG's." (*9*)

In order to provide some estimate of the public health significance of the individual high measurement of 9.7 pc per gram of calcium, it can be compared with some fraction or multiple of 50 pc despite recognition of the fact that the source of the strontium–90 is unquestionably fallout from weapons tests and therefore not a situation covered by the FRC guidance.

For convenience of reference, selected bone concentrations corresponding to "ranges of transient rates of daily intake" are given in table 4.

TABLE 4.—STRONTIUM-90 SKELETAL CONCENTRATIONS CORRESPONDING TO FEDERAL RADIATION COUNCIL RANGES

[pc/g calcium]

FRC Range	Population "Average"	Individuals
I	0–5	0–15
II	5–50	15–150
III	over 50	over 150

The highest single value for an individual, 9.7 pc strontium–90 per gram of calcium, was measured in the 0–4 age group in 1962. This finding corresponds to a daily intake which is less than the upper level of the Federal Radiation Council Range I for a measurement on an individual.

Where comparable with respect to age and year of death, the overall results are slightly above those reported by Rivera (*4,5*) although no single value exceeds 10 pc per gram of calcium.

The very fact of death at a young age implies that the deceased are not randomly drawn from the exposed population. An appropriate sample would require taking into account factors affecting intake such as age, sex, geographical area and economic status, and those affecting calcium and strontium metabolism as reflected by the nature of the cause of death.

Since specimens are almost always collected at autopsy and submitted to the program by voluntary arrangments, it is difficult to satisfy the ideal sampling criteria. Nevertheless, some criterion of adequacy of numbers is called for and it is suggested that 0.1 percent of the annual number of deaths under 1 year of age and 1 percent in each of the other groups through age 24 be used. Using 1960 mortality data (*10*), this would provide about 700 specimens, 100 under 1 year of age and 600 from 1–24 years. These numbers are proposed for the determination of national averages. The same proportions are recommended for each of the regions within the country. On the basis of the experience to date this is a feasible goal.

As the number of samples reported does not yet approach those proposed for a "suitable sample of the exposed population," the mean values shown in table 2 have not been compared with each other or with skeletal concentrations corresponding to FRC ranges for population averages.

Acknowledgments

This program is dependent on the many resources of the Division of Radiological Health, Public Health Service, and the cooperation of the participating pathologists, medical examiners and coroners. We regret that we cannot list them by name nor all of the staff of the Division who have made significant contributions. However, special recognition must be given to Dr. Abraham S. Goldin, Deputy Officer in Charge, Northeastern Radiological Health Laboratory; Edmond Baratta, Chief of Analytical Services, Northeastern Radiological Health Laboratory; and Louise French and Virginia Canavin of the Research Branch.

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ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U. S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant perimeter surveys are required.

Summaries of the environmental radioactivity data for 23 AEC installations have appeared periodically in *RHD* since November 1960. Summaries follow for Feed Materials Production Center (FMPC), Fernald, Ohio and Feed Materials Production Facilities (FMPF), Weldon Springs, Missouri.

Releases of radioactive materials from these plants for the periods covered in the reports below are regulated in accordance with standards set forth in the Federal Register, Title 10, Part 20. The appropriate concentration standards are given in table 1.

TABLE 1.—MAXIMUM PERMISSIBLE CONCENTRATIONS PERTAINING TO ENVIRONMENTAL MONITORING AT FMPC AND FMPF [a]

Radionuclide	Air (pc/m^3)	Water (pc/liter)
Total activity in air if α emitters and Sr^{90}, I^{129}, Pb^{210}, Ac^{227}, Ra^{228}, Pa^{230}, Pu^{241}, and Bk^{249} are not present [b]	100	—
Total activity in water if Sr^{90}, I^{129}, Pb^{210}, Po^{210}, At^{211}, Ra^{223}, Ra^{224}, Ra^{226}, Ac^{227}, Ra^{228}, Th^{230}, Pa^{231}, Th^{232}, and Th-nat are not present [b]	—	3,000
Uranium-natural	2	20,000

[a] The concentration standards given here were taken from the Atomic Energy Commission's regulation 10CFR, Part 20 (Federal Register, November 17, 1960).

[b] "Not present" implies that the concentration of the nuclide is small compared with its appropriate MPC. According to Federal Register, Title 10, Part 20, August 9, 1961, a group of nuclides may be considered not present if the ratio of each nuclide to its appropriate MPC is equal to or less than 1/10 and if the sum of these ratios for the group in question is equal to or less than ¼.

1. Feed Materials Production Center, July 1962-December 1963

National Lead Company
Fernald, Ohio

The Feed Materials Production Center (FMPC), is operated by the National Lead Company of Ohio (NLO) for the AEC. The location, as related to populated areas, is shown in figure 1.

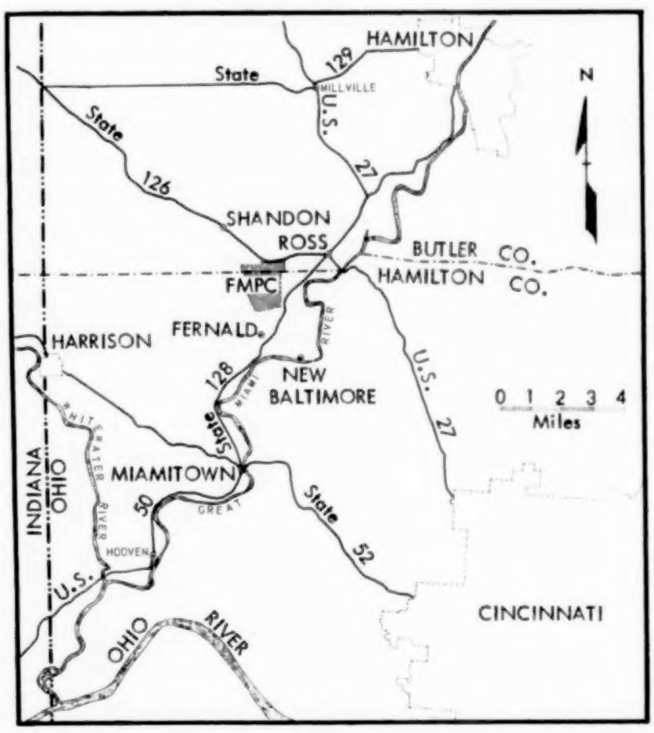

FIGURE 1.—AREA MAP OF FEED MATERIALS PRODUCTION CENTER

Operations at this project deal with the processing of high-grade uranium ores and ore concentrates to produce metallic uranium and with the fabrication of the metal into fuel elements.

An environmental survey program of air and water sampling is maintained to check the effectiveness of dust collectors and waste treatment processes.

Air Monitoring

FMPC uses dust collectors, such as bag collectors, electrostatic precipitators and scrubbing towers, which remove nearly all of the airborne particulates generated during the many plant operations. The environmental air sampling program provides an indication of the amount of material released into the atmosphere.

On-site samples were taken at four permanent sampling stations located at the four corners of the production area shown in figure 2. Off-site samples were taken by a mobile unit operated at various distances and directions from the plant determined by local meteorological-conditions on the day of sampling. The data for the off-site samples are averaged in groups according to distance from the production area. Concentrations of uranium and total activity of airborne particulates sampled at on-site and off-site locations are given in table 2.

Water Monitoring

Continuous daily samples, collected from the combined sewer leading from the FMPC site to the Great Miami River are analyzed for uranium and total activity. The combined sewage is composed of treated liquid effluent from the production plants, water treatment plants waste effluent, storm sewer discharge, and treated sanitary sewage. Using the data from the combined sewage samples and stream flow data for the Great Miami River, the FMPC contribution to radioactivity concentrations in the river may be calculated. To check the calculated results, weekly upstream and downstream spot samples are taken. Table 3 presents the calculated and the spot check river concentrations. Since the calculated concentration represents only the contribution from FMPC, it should be compared with the difference of the upstream and downstream measurements. Sampling points are shown in figure 2.

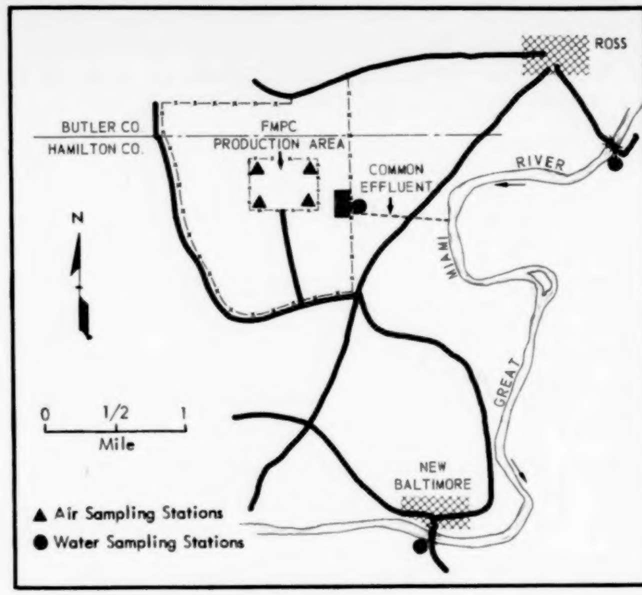

FIGURE 2.—AIR AND WATER SAMPLING STATIONS, FEED MATERIALS PRODUCTION CENTER

Previous coverage in *RHD:*

Period	Issue
January 1959-June 1960	*April 1961*
July-December 1960	*June 1961*
January-June 1961	*December 1961*
July 1961-June 1962	*March 1963*

TABLE 2.—RADIOACTIVITY OF AIRBORNE PARTICULATES, FMPC

[Average concentrations in pc/m³]

Location	Second half 1962			First half 1963			Second half 1963		
	No. of samples	Uranium	Total activity	No. of samples	Uranium	Total activity	No. of samples	Uranium	Total activity
On-site									
Southwest	25	0.16	3.16	25	0.28	6.09	27	0.24	1.86
Northwest	25	0.06	2.39	24	0.11	5.27	27	0.12	1.61
Northeast	23	0.14	2.78	26	0.33	6.00	27	0.25	2.10
Southeast	24	0.13	2.75	25	0.24	5.11	27	0.17	1.64
All on-site samples	97	0.13	2.77	100	0.24	5.62	108	0.20	1.80
Off-site									
0–2 miles from FMPC	6	0.09	5.08	23	0.11	6.25	30	0.34	2.54
2–4 miles from FMPC	6	0.18	3.86	16	0.09	5.10	26	0.08	1.57
4–8 miles from FMPC	3	0.04	0.65	12	0.05	3.59	26	0.06	2.07
8–10 miles from FMPC	2	1.07	5.52	4	0.06	3.80	8	0.05	1.07
All off-site samples	17	0.22	3.67	55	0.09	5.16	90	0.16	1.99

TABLE 3.—CONCENTRATIONS OF URANIUM AND TOTAL ACTIVITY IN THE GREAT MIAMI RIVER, OHIO

[Average concentrations in pc/liter]

Location	Method of determination	Second half 1962			First half 1963			Second half 1963		
		No. of samples	Uranium	Total activity	No. of samples	Uranium	Total activity	No. of samples	Uranium	Total activity
Sewer outfall	Calculated from sewer concentrations and stream data (continuous sampling).	184	126	26	181	5	6	184	12	12
Upstream	Spot samples	32	9	36	28	7	6	26	5	28
Downstream	Spot samples	32	16	50	31	1	8	67	13	48
Difference		—	7	14	3	6	2	41	8	20

2. Feed Materials Production Facilities, July 1962-December 1963

Malinckrodt Chemical Works
Weldon Spring, Missouri

Environmental monitoring results at the Feed Materials Production Facilities (FMPC), are reported in uranium concentrations since uranium ore concentrates constitute the primary feed material.

Process chemical wastes and other process residues are permanently retained in storage facilities located at both the plant site and two storage sites located adjacent to the Lambert-St. Louis Municipal Airport and at a quarry near the Missouri River (see figure 3). The plant process sewer, which carries the remaining water effluent from the operations into the Missouri River, is automatically sampled daily to permit continual measurement of any release of uranium-bearing material into the river.

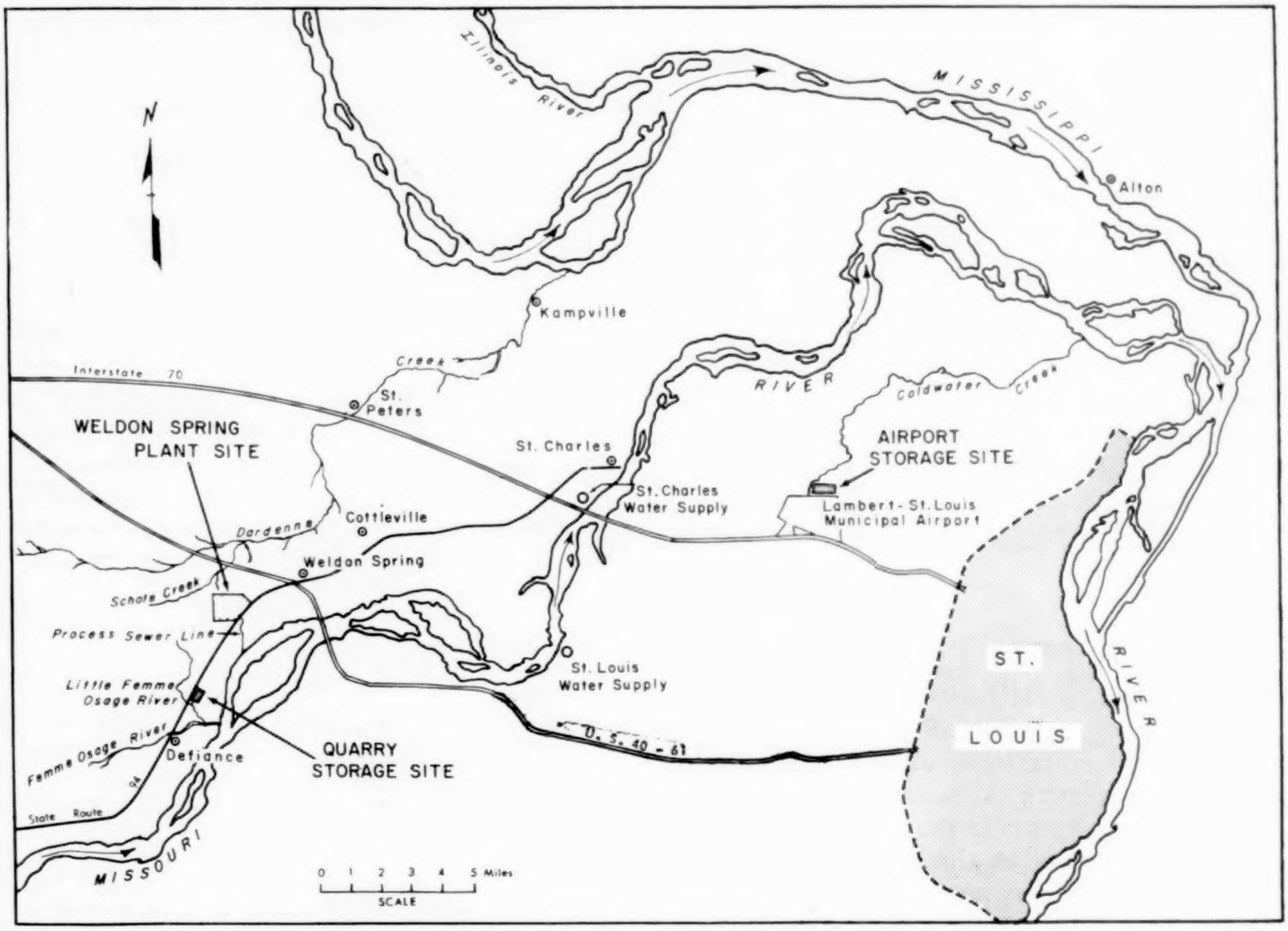

FIGURE 3.—LOCATION OF FEED MATERIALS PRODUCTION FACILITIES, WELDON SPRING, MO.

Air Monitoring

Monthly air samples are collected along the plant perimeter by 9 high-volume sampling pumps. Midway during the second half of 1962 three of the samplers were moved from their former locations on building roofs to their present perimeter locations. Some of the averages for the second half 1962 given in table 2 therefore are made up of data from two locations but the same general direction from the area of discharge.

Semiannual air samples are collected at 4 points on the perimeter of the airport storage site, and monthly air samples are collected at the south edge of the quarry. Semiannual average uranium concentrations are reported in table 4. Averages ranged from 0.05 percent to 23 percent of the environmental MPC for uranium in air.

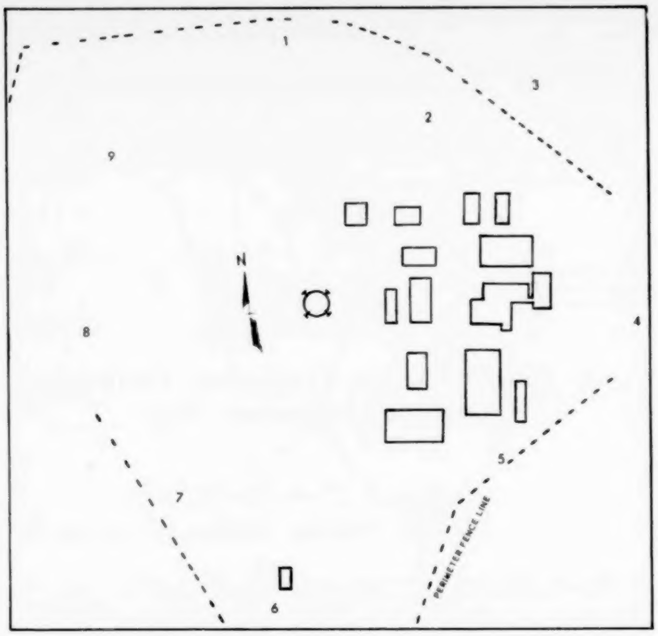

FIGURE 4.—PERIMETER AIR SAMPLING STATIONS, WELDON SPRING PLANT

TABLE 4.—URANIUM CONCENTRATIONS IN AIR—FMPF

[Average concentrations in pc/liter]

Site	Station location (see figure 4)	Second half 1962		First half 1963		Second half 1963	
		Number of samples	Uranium	Number of samples	Uranium	Number of samples	Uranium
Plant	1	3	0.167	5	0.121	6	0.17
	2	3	0.048	6	0.020	6	0.28
	3	3	0.064	6	0.022	6	0.054
	4	3	0.062	4	0.085	6	0.085
	5	3	0.038	6	0.258	6	0.46
	6	3	0.106	6	0.057	6	0.017
	7	3	0.057	4	0.178	6	0.065
	8	3	0.123	5	0.074	6	0.16
	9	3	0.116	3	0.053	6	0.21
	Average	—	0.087	—	0.096	—	0.166
Quarry	South edge	6	0.013	6	0.096	6	0.014
Airport	North	1	0.070	1	0.027	1	0.015
	West	1	0.100	1	0.027	1	<0.001
	East	1	0.045	1	0.090	1	0.011
	South	1	0.033	1	0.170	1	0.012

[a] Plant site data given here represent the fourth quarter only because sampling locations were changed at the end of the third quarter. Third quarter plant site station averages ranged from 0.004 pc/m³ to 0.380 pc/m³ with an average value of 0.083 pc/m³.

Water Monitoring

In addition to daily samples from the plant process sewer, monthly off-site water samples are collected from lakes and streams located within the plant's watershed, the Missouri River, and streams near the quarry and airport storage area sites at the points indicated in table 5. Average uranium concentrations ranged from 0.01 percent to 4.4 percent of the environmental MPC.

Previous coverage in *RHD:*

Period	Issue
January 1959-April 1960	*November 1960*
July-December 1960	*November 1961*
January-June 1961	*November 1961*
July-December 1961	*July 1962*
January-June 1962	*November 1962*

TABLE 5.—URANIUM CONCENTRATIONS IN WATER—FMPF

[Average concentrations in pc/liter]

Sampling locations	Second half 1962		First half 1963		Second half 1963	
	Number of samples	Uranium	Number of samples	Uranium	Number of samples	Uranium
Process sewer, plant site	120	480	124	860	120	890
Missouri River sampling points:						
Defiance, upstream	6	4	2	2	2	4
Femme Osage junction, upstream	6	1	2	1	2	1
Process sewer outfall	6	200	6	210	0	—
U. S. Highway 40-61, north side	6	2	0	—	0	—
U. S. Highway 40-61, south side	5	2	2	8	2	10
St. Louis city water plant intake	6	2	2	2	2	12
St. Charles city water plant intake	6	1	2	8	2	5
Plant offsite sampling points:						
Lake, east of plant	6	2	2	4	2	13
Lake, north of plant	6	1	2	1	2	6
Lake, west of plant	6	8	2	2	2	4
Lake, south of plant	6	1	2	10	2	16
Dardenne Creek, upstream	6	1	2	4	2	6
Dardenne Creek, Cottleville Bridge	6	3	2	7	2	4
Dardenne Creek, St. Peters	6	2	2	4	2	6
Dardenne Creek, Kampville	6	2	2	7	2	8
Schote Creek, upstream	6	1	2	2	1	5
Schote Creek, downstream	6	8	6	18	6	29
Plant surface drainage, west	6	130	6	140	6	130
Plant surface drainage, north	6	170	6	160	6	180
Quarry offsite sampling points:						
Little Femme Osage (LFO), ¼ mi. upstream	6	<1	2	<1	2	1
Branch, LFO, ¼ mi. upstream	6	1	2	<1	2	2
LFO, at quarry discharge culvert	6	<1	6	50	6	2
LFO, ¼ mi. downstream	6	<1	2	<1	2	2
LFO, 1¼ mi. downstream	6	<1	2	<1	2	2
Airport offsite sampling points:						
Cold Water Creek, southwest corner of site	1	2	1	<1	1	2
Cold Water Creek, northwest corner of site	1	2	1	<1	1	2
Drainage ditch, north of site	dry	—	1	140	1	90
After site pond discharge	1	100	1	<1	1	1

REPORTED NUCLEAR DETONATIONS, APRIL 1964

Four underground nuclear detonations at the Nevada Test Site during April 1964 were announced by the Atomic Energy Commission. The tests conducted on April 14, 15 and 29 were of low yield, and the test conducted on April 24 was of low intermediate yield. (Low yield range is defined as less than 20 kilotons; low intermediate yield means 20 to 200 kilotons.) Arbitrary reference numbers 152 through 155 were assigned in the order of the test dates by *Radiological Health Data*.

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UNITS AND EQUIVALENTS

Symbol	Unit	Equivalent
Bev	billion electron volt	
cpm	count per minute	
dpm	disintegration per minute	
g	gram	
kg	kilogram	1 kg = 1000 gm = 2.2 pounds
km^2	square kilometer	
kvp	kilovolt peak	
m^3	cubic meter	$1\ m^3 = 1000$ liters
ma	milliampere	
mas	milliampere-second	
Mev	million electron volts	
mi^2	square mile	
ml	milliliter	
mm	millimeter	
mrad	millirad	
mrem	millirem	
mr/hr	milliroentgen per hour	
mμc	millimicrocurie	1 mμc = 1 nc
nc	nanocurie	1 nc = 1000 pc = 1 mμc $=10^{-9}$ curies
nc/m^2	nanocurie per square meter	$1\ nc/m^2 = 1\ m\mu c/m^2 = 1{,}000\ \mu\mu c/m^2 = 1\ mc/km^2 = 2.59\ mc/mi^2$
pc	picocurie	1 pc = 1 μμc $= 10^{-12}$ curies
r	roentgen	
μμc	micromicrocurie	1 μμc = 2.22 dpm

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	ter' a
10^{9}	giga	G	ji' ga
10^{6}	mega	M	meg' a
10^{3}	kilo	k	kil' o
10^{2}	hecto	h	hek' to
10	deka	da	dek' a
10^{-1}	deci	d	des' i
10^{-2}	centi	c	sen' ti
10^{-3}	milli	m	mil' i
10^{-6}	micro	μ	mi' kro
10^{-9}	nano	n	nan' o
10^{-12}	pico	p	pe' co
10^{-15}	femto	f	fem' to

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